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PHYSICS.—*The beginnings of physics. I.—The quest for general principles.*[1]

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When, where and how did physical science begin? To answer these questions, we must first of all specify what is meant by physical science. This we can do only by tracing its outline in historical perspective to the central focus of all ages. But considerable care must be exercised in allowance for the distorted lines of particular periods and for the faint marks of primitive times. Shall we seek the origin of science in the early use of tools? If so, archaeological history assigns the drill and the potter's wheel to some time before 3000 B.C. Even as to-day, however, a child acquires mastery of a hoop without perceiving the latent dynamical principles, so too the ancients had no knowledge commensurate with their mechanical skills. It would seem better to seek for the beginnings of science in the first conscious investigations of nature. At once, we think of the early cosmogonies of mythology. But we hesitate to ascribe to these the spirit of science. Although both mythology and science start with keen observations, the former regards men; the latter, things. Mythology interprets nature subjectively in terms of human experience; science describes it objectively in terms of its own. Such methods are incompatible. Indeed, science could arise only if the old way of thinking were completely discarded. For mythology could be modified in no simple manner, inasmuch as anything new would have to be added to the old for safety's sake. Consequently, a different attitude had to be developed—not a broadening, but a narrowing of animistic views—so that objective study would be ultimately possible. Such a reactionary method necessitated an intellectual revolution for its inception. And this is just what took place in Greece about 600 B.C. when thinkers began the quest for general principles which would describe nature without recourse to caprice.

New ideas germinate readily in a new country. And in a certain sense Greek Ionia, which was the western part of what is now Asia

[1] Received July 2, 1934.

Minor, was "a country without a past." Its inhabitants were adventurers who had come from Attica after the Dorian invasion from the north. They had left behind the decadent religion molded by Hesiod's *Theogony*. The Ionians, therefore, were free to explore unrestricted realms of thought. Their curiosity created pure research, that disinterested search for truth which is immortalized in the oath of Hippocrates[2] of Cos (c.400 B.C.). To be sure, vestiges of Olympian polytheism always remained. For example, Thales, one of the seven wise men of Greece, said with reference to magnetism, which he had discovered, "All things are full of gods." But this is trivial compared with the magnificent conception of a first cause, which the Ionian philosophers proposed as materialistic in nature. Later this was extended to the Aristotelian hierarchy of four causes, in which teleology humanized logic with ethics. Hence, in time, philosophy became a way of life and the "lovers of wisdom" adopted this new *raison d'être* for their studies. Their criterion was so universally accepted that a divergence between professional philosophy and science has been perpetuated to this day.

Claims have been made that science was transmitted in the contacts of the sea-loving Ionians with Chaldean astronomers and Egyptian geometers. There is no doubt that the acquisition of many facts is to be attributed to the excursions of these men from Eastern Greece. But the philosophical interpretation of the facts was peculiarly their own. The astronomy of Chaldea was mainly astrology interspersed with some practical methods for predicting eclipses. The geometry of Egypt was, at first, no more than empirical mensuration. It took a Pythagoras to realize the significance of the 3–4–5 rule used by the "rope-stretchers" along the Nile. As for the older civilizations of India and China, the historical facts are too few to warrant more than vague conjectures. What is definitely known is that an entirely different approach to the understanding of the universe was begun in Greece more than a century before the "golden age" of Pericles.

The scientific method of the Greeks has often been ridiculed because of its lack of experimental justification, not to mention its permeation with speculation. We note, however, that even the latter is decidedly experiential. Do not savages fear the potentially evil spirits lurking in the clouds because storms actually do rage? The Greeks could hardly be said to be less observant. Indeed, the literary

[2] Dates and spellings of Greek names are taken from the *Introduction to the history of science*—GEORGE SARTON (1927).

descriptions of Homer and the delicate sculpture of Phidias are eternal evidence of their attention to minute details. The biological classifications and records of Aristotle still excite the admiration of naturalists. What amateur of science has not been thrilled by Hipparchos' discovery of the precession of the equinoxes? As a matter of fact, such instances can be so readily multiplied that the speculative character of Greek conclusions can not have been inherent in their observations. On the contrary, it grew out of their unobserved significance. How else can one account for nature being accepted as the giver, but not as the judge of theory? Induction, it is true, was used. But in what way? Solely as the grouping together of similar observations. Nature was never examined as to the reason for their similarity or the possibility of their not being universal. The facts were regarded as concrete symbols of abstract reality; they were looked upon as incidental expressions. Accidental impressions were overlooked; for epistemology with its incisive analysis of mind itself was yet to come. Even Protagoras' hint that man is a measure of all things and Xenophanes' earlier application of it to the anthropomorphic gods were but eddies in a tide of self-satisfaction. And so when objections to any hypothesis were made on the basis of new facts, the tendency was to deny these rather than to modify the theory.

To-day we can understand all this psychologically as the "will-to-live" of their newly born enthusiasm, the supreme power of thought. Sublime as this may have been in the mind of Plato (or later of Hegel), however, it has been found to take too little cognizance of man's abilities and of nature's intricacies. Modern physicists very guardedly refrain from any semblance of finality in their small restricted domain. But in the childhood of science the intellect loomed as an all-powerful giant. Had not the dialectic method of Socrates disarmed the sophisticated sophists and freed truth from their mesh of error? The Greeks were eager to apply it unreservedly to everything. Moreover, the rational architecture of the universe seemed to them to call for an investigation of the universal elements of design. So experiment was cast aside as dealing with comparatively insignificant matters. Nor did it adapt itself later either to the ethical philosophies of the Greek world or to the Christian theology of the Roman empire. In an age, therefore, when methods were being formulated, the *a priori* method won support because of its quick returns. The operation of a similar natural selection can be observed to-day in newly developed fields

where the base achieving of results receives more plaudits than the acid testing of methods.

The real contributions of Greece to physical science have been the enunciation of general principles and the application of mathematical symbolism. When we compare these advances with the blind ignorance of the preceding age and with the stereotyped knowledge of the following one, we are almost converted to a belief in a "heroic age of science." We shall examine the second contribution in Part II. For the present, let us take up the general hypotheses in logical detail in order that too many lacunae may not give them the appearance of being merely a catalogue of desultory opinions. For one can trace a definite trend toward a clarification of concepts. Indeed, in some instances the final ideas seem almost identical with our own, but the language expressing thoughts must always be understood in the context of the age considered. In particular, it must be borne in mind that whether or not any general theory is ultimately successful is not indicative of its importance when first presented, inasmuch as the success of speculation is no more to be credited than its failure. Because of subtle inferences that can be made, true results by false methods are just as confusing, as worthless results by genuine methods.

Is it possible to give a unified materialistic explanation of nature? In other words, can one rationally interpret phenomena on the basis of a simple kinematical picture? The very question is startling. It becomes more so when we pause to examine its tacit assumptions as understood by the Greeks. In the first place, there is a belief in the uniformity of nature, i.e., a certain regularity of sense-perceptions that seems to invite the direct application of causality, as for example the continual succession of day and night. Secondly, a faith in man's capacity for understanding such orderliness is affirmed. Finally, quintessential truth is unreservedly sought. To-day we still ask the same question, but our frank skepticism calls boldly for specific qualifications. We feel free to consider the uniformity in certain cases an average condition, as when a large lake appears calm because its playful ripples escape our notice. Then too, man's ability to synthesize his experiences, we believe, arises partly from his own peculiar analyses. The strange imprint upon nature is his own. As for the true explanation of the universe, this has been abandoned as a scientific project *per se*, and has been replaced by the more modest search for an adequate description of it. Perhaps, there is a unique picture of the real world; then again, there may be several that are

equally satisfactory. Science is concerned with the sufficiency of its theories, not with their necessity; at present, of course, it will be content to find a single one. On the other hand, it is interesting to note that several pictures may be necessary (cf. the wave-theory and the corpuscular theory to-day). The following example may serve to illustrate the modern viewpoint. One says, "He was a lion in the fight." We all understand what is meant. The picture aptly describes a certain characteristic of the individual, but is the picture literally true? Was there actually a metamorphosis? That is a matter which cannot be settled without additional information. Furthermore, we note that another picture might tell the story just as well. One might also say, "He would not give up the ship." So, too, science leaves this sense of the reality of its picturesque descriptions to be determined by other means. Let us now examine the hazy pictures which were sketched by the Greeks.

Thales of Miletos (n.624 B.C.), the father of physics, selected water as the primordial substance. Despite the fact that none of his writings are extant, we can reasonably attribute his choice to its omnipresence. Water is everywhere; in the rains that descend upon the earth, in the waters under the earth, in the oceans about the earth. It permeates all substances so that their physical properties are dependent upon their content of moisture. Even life is conditioned by its presence. This universality of water served as the first requisite of the basic material. Furthermore, the readiness with which water transforms into solid and into vapor hinted at mobility, another necessary characteristic, but Thales himself gave no particular explanation of any such changes. In order to do so, his pupil Anaximander (c.610–545 B.C.) decided to introduce a different primary substance which was an "ageless and deathless" substratum of matter. This unchanging reality, which he called φύσις ("characteristic property of something"), had derivatives such as water and air resulting from its natural dissociation into pairs of neutralizing components (cf. the rainbow from sunlight). For as one observes phenomena, one is impressed with the duality of changes; here drying occurs, there moistening; now heating, then cooling. To be sure, this is merely the twofold aspect of the reversibility of changes, but it is susceptible to manifold interpretations. In the one we are considering, the very constancy of such changes necessitated a continuous dissociation of the primary substance so that it had to be more plentiful than sand on a beach washed silently by time-telling tides. But no common material is so abundant; hence, the need for something

"boundless" and insensible. Thus for the first time an eternal submatter (like the electrons, protons, etc. of modern physics) had to be proposed. The significance for us lies in this choice of a hypothetical substance to account for actual materials, an unseen universe to represent the visible one. As for the principle of indestructibility which was also suggested, it has been invoked in modern times for the conservation of mass, the conservation of energy, and the conservation of electric charge. Challenged in the 20th century, it has been merely transferred from matter (i.e., charge) to a more fundamental concept, viz., that of energy, so that matter itself is to be looked upon as an accidental form of energy. It would be of interest to examine Anaximander's doctrine of an eventual compensation of the "opposites" to produce a changeless universe and his view of the earth as freely supported. We prefer, however, to confine our attention more strictly to the development of ideas which to-day are the tacit assumptions of physics ("the study of φύσις"). Such is the proposal of a unified, materialistic explanation of all phenomena, which was a volcanic eruption in a world governed by the uncontrollable passions of humanized gods and enveloped in the dark atmosphere of ignorant superstition.

Another important step in the search for unity was made by Anaximenes (fl.546 B.C.), an associate of Anaximander. Retaining the idea of the "boundless," he decided it was air, but rejected Anaximander's other views as so indefinite as to be meaningless. The reason he chose air in preference to water is evident in his way of accounting for the derivatives of the "boundless." When one whistles, the air is cool; when one yawns it is warm. He reasoned, therefore, that condensation produced cold air, whereas rarefaction produced warm. The variety of materials could thus be explained in terms of the variations of a single substance, e.g., ice, water, water-vapor. But to ascertain, in general, whether materials are fundamentally distinct or different forms of some single identity is a theoretical problem which cannot be uniquely solved. Then, too, what may appear simple at first sight may prove too complicated to establish as such. And so we must regard the entire proposal of Anaximander as a simple hypothesis which failed of a simple proof. For he advanced the notion that fire was air in a very rare state. Upon condensation it became first wind and then cloud. Obviously, condensed cloud gave rise to water which disappeared into earth itself, and condensed finally into stone. Hence, the process of transformation, which his predecessor had left indeterminate, he was able to trace in the varying

conditions of air. Above all, the states of heating and of drying which had previously been logical hybrids of indeterminateness and mobility could be stated by use of condensation and rarefaction (cf. the whistling example, above). Although the advantages of thus describing qualitative differences by quantitative variations in state is too common to-day to be fully appreciated it was a clear-cut departure from the current meanderings at that time. For fluid theories are usually the first conceived in any age—perhaps, because of their ease of apprehension. One still recalls the phlogiston of the 18th century and the caloric of the 19th (it is strange that Lavoisier disproved the former, but approved of the latter)—not to mention the "neutrinos" of 1934. And so it is to the credit of the Greeks that the philosophy of Anaximenes became the accepted one of the Milesian school at an early stage.

Heraclitos of Ephesos (fl.500 B.C.), who desired to be considered apart from the other Ionian philosophers, perceived in the constancy of change, not so much a transformation of a single substance, as a single transforming. In other words, he sought unity in the activity rather than in the passive object. For example, consider the burning of wood. The flame plays from place to place while the burning steadily proceeds. It is change alone which is lasting; all else is ephemeral. And what is the most spectacular producer of change but fire? Out of fire, therefore, comes everything, as when the burning wood yields smoke and ashes as by-products. To Heraclitos this illustrated the essential nature of the universe. For from the fire of the sun leaped "fiery water-spouts," which burned and left earth as a residue. The earth was then carried away to the sea where it returned to the sun by the evaporation of the water. The cycle was repeated. More than that, it was reversible so that at any instant the sea should be considered a mixture of fiery water-spouts becoming earth and of earth becoming fiery water-spouts. These opposing transformations so balanced each other that one might appropriately speak of their harmony from the analogy of a note produced by the pull and strain on a string of a lyre. For is not the warm ever cooling; the cool, warming? Each is only a different aspect of the same equilibration. Fantastic as this may appear, Heraclitos made a real contribution in his emphasis upon dynamic equilibrium, viz., his subjecting mobility, as well as matter, to definite laws. We note in all these speculations a gradual insistence upon logical application rather than poetic license. But weak spots of analogies were often left unprotected and became sores for later irritation. In this case, by the way, what was

the exact relation between fire and its by-products (not solved until the 18th century)? This question soon absorbed the attention of the philosophers until two answers came into vogue; one denied the very existence of change, the other affirmed the existence of several primary substances instead of a single one. In fine, the quest for a primordial substance and the emphasis upon motion were found to be incompatible.

It was Parmenides of Elea (c.539 B.C.), who pointed out that the "real" must be uncreated and indestructible if matter alone could be thought, but how, then, could one interpret the transformations of the "real"? Manifestly on a monistic view these were incredible. All appearance of change was necessarily an illusion of the senses, as well as any sensation accompanying it. This meant that the world was one homogeneous body of matter without any space whatsoever and that motion was impossible. This strange attitude, which was only the logical development of a purely monistic view, was responsible for the subsequent abandonment of monism. Pluralism of some kind was adopted—until reality was assigned not only to sub-matter, but even to the non-corporeal. Our chief concern lies in the discrediting of the senses and the insistence upon logical consistency. For he stressed the need of differentiating between primary matter and its secondary qualities. The world of nature became even more a world of the mind.

The first attempts to use more than one funadmental substance were in the form of combinations of those which had already been proposed for a single one. Oenopides of Chios (c.500–430 B.C.) chose fire and air; Xenophanes of Colophon (fl.540 B.C.) preferred water and earth. It remained for the Dorian philosopher, Empedocles of Acragos (c.490–435 B.C.), to combine all four. Indeed, this was not wholly unreasonable inasmuch as this group included a solid, a liquid, a gas and ethereal fire. He really introduced the idea of "elements" (a name employed first by Plato), which were constituents of all materials. Strictly speaking, the early Greek philosophers recognized six. For in addition to fire, air, water and earth, love and strife were considered to have certain corporeal properties such as length and weight. These last two elements (like our modern attractive and repulsive forces) were supposed to set the others in motion. Combinations of any number or of all six were assumed to produce the various kinds of matter. To cite an instance, "bone consists of 4 parts of fire, 2 parts of earth and 2 parts of water." Of course, *a priori* methods were used to determine the relative amounts in a

composition. But the idea of combinations of a few elements to account for many substances proved very potent throughout the growth of science; and we must remember that it was the atomists who first took up this problem of the way elements combine in order to explain the secondary characteristics of matter composed of similar particles. The same foundations of physics were laid carelessly on the shifting sands of speculation, before they were laid critically on the bed-rock of experiment.

In the meantime, another philosopher, Anaxagoras of Clazomenae (c.499–428 B.C.), one of the first martyrs of the freedom of thought, suggested at Athens the very opposite extreme to the unity advocated by Parmenides. The following quotations[3] epitomize his viewpoint. "How can hair come from what is not hair, or flesh from what is not flesh?" (The argument is still used by opponents of certain biological theories.) "For there is no least of what is small; there is always something still smaller. For it is impossible that that which is should cease to be by being divided. In everything there is a portion of everything except mind." Although this proposal was diametrically opposed to that of Parmenides, it was raised to solve the same dilemma, viz., that creation and change were impossible because matter could not come from nothing. There is no doubt that Anaxagoras offered a rational, though not reasonable, answer. For there were just as many seeds (to borrow the name used by Aristotle) as substances. If one asked, then, how bread could become flesh upon digestion, the ready reply was that bread had flesh latent in it. To be sure, the "flesh-seeds" had to be very minute and sparsely scattered throughout the bread. Otherwise, as Anaxagoras might note, one would have to expect wood shavings when cutting hair. The seeds were to be regarded as infinitely divisible, but never lost. Thus the permanence of substances was maintained despite disruptive changes. Somewhat apart from other seeds were those of the mind. Like Empedocles' strife and love these corporeal bits caused motion. Certainly Anaxagoras' solution of the problem of change was naïve. It was not satisfactory, however, in that the sufficiency of an explanation is not the only objective of natural philosophy. It must be simple also. (Recall the remark of Kepler: "Nature loves simplicity and unity"—or at least, mankind loves them.) And so atomism arose out of a desire to reduce the number of basic substances and to refute the Eleatic notion that phenomena were illusions. Let us turn again to Parmenides' views.

Zeno of Elea (fl.402 B.C.) introduced an entirely new method of

[3] *Source book in ancient philosophy*—CHARLES M. BAKEWELL (1907) 51.

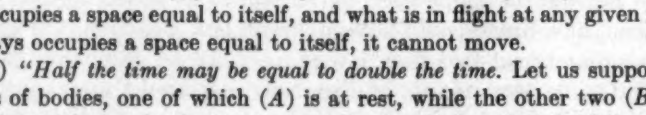
proof in defense of Parmenides' monism. It was essentially a *reductio ad absurdum*. The object was to show that an opponent's arguments were erroneous by deducing some absurd conclusion, or better, to obtain incompatible conclusions from the same hypothesis. Zeno used this method chiefly to disprove the pluralistic mathematics of the Pythagoreans, e.g., that space was made up of a number of mathematical units. "A point is unity having position." His famous paradoxes hinted at the great caution that must be employed, not only in the technical application of mathematics to physical problems, but also in the philosophical interpretations. For mathematics can express only what it has been asked to express. The paradoxes[4] themselves illustrate most clearly Zeno's method.

(1) "*You cannot cross a race course.* You cannot traverse an infinite number of points in a finite time. You must traverse the half of any given distance before you traverse the whole, and the half of what remain before you can traverse the whole. This goes on ad infinitum, so that there are an infinite number of points in any given space, and you cannot touch an infinite number, one by one, in a finite time.

(2) "*Achilles will never overtake the tortoise.* He must first reach the place from which the tortoise started. By that time the tortoise will have got some way ahead. Achilles must then make up that, and again the tortoise will be ahead. He is always coming nearer, but he never gets up to it.

(3) "*The arrow in flight is really at rest.* For if everything is at rest when it occupies a space equal to itself, and what is in flight at any given moment always occupies a space equal to itself, it cannot move.

(4) "*Half the time may be equal to double the time.* Let us suppose three rows of bodies, one of which (A) is at rest, while the other two (B, C) are moving with equal velocity in opposite directions. (See the following diagram.) By the time they are all in the same part of the course B will have passed twice as many bodies in C as in A. Therefore, the time which it takes to pass C is twice as long as the time it takes to pass A. But the time which B and C take to reach the position of A is the same. Therefore, double the time is equal to the half."



The mathematical subtleties involved in these problems are continuity, infinitesimals and absolute infinity or transfinite numbers so that even to-day the explanations are far from simple. The funda-

[4] *Early Greek philosophy*—JOHN BURNET (3rd ed. 1920) 318.

mental question is whether or not the limit of the variable is reached by it, e.g., whether Achilles ever does overtake the tortoise. But mathematically, this must be defined to suit the physical observation, and so Zeno's difficulty is removed. Here we are face to face with a typical example of mathematical logic transcending intuitive physics or, in other words, a method of analysis which cannot be analyzed into simple, physical commonplaces just as the recent quantum mechanics cannot be understood by reduction to familiar descriptive models. As for Zeno, he was content with having vitiated the arguments for more than one "real," by showing that motion could not be conceived in terms of a finite number of space-units. Of course, infinite divisibility of space was rejected because it seemed to lead to an infinite number of finite parts (again a question of the meaning of a limit such as zero).

It may seem strange that a theory of invisible atoms should have its origin in a refusal to disbelieve what is seen. Yet this has always been the case from the time they were first proposed by Leucippos of Miletos (c.460 B.C.) to the 20th century. Starting with a firm belief that knowledge is acquired through the senses, he proceeded to solve the logical difficulties encountered by Anaxagoras and by Zeno. First of all, he assigned existence to the non-corporeal and classified space as such so that motion was no longer an illusory experience, but again an accepted fact. Secondly, he postulated atoms ("uncut bits"), which were all of one substance, homogeneous, hard and indivisible. But why, we may ask, these particular attributes? The first two made it possible to retain the unifying principle of a single material. Instead of the one plenum of Parmenides, however, each atom now possessed such properties. The hardness of the atoms insured their changelessness and timelessness. Finally, their indivisibility relieved everyone of any fear that matter might fritter away into dust like the seeds of Anaxagoras. Let us consider the reasons adduced to support the atomic hypothesis. It was natural to suppose that there is a physical limit to the cutting of any body. The knife itself guarantees that. Such an undivided portion could usually be seen, so that one had to think of the cutting as being repeated indefinitely until the next cutting could not even be imagined. This final uncut residue, with its finite magnitude to account for the size of ordinary bodies, was an atom. Although this argument from analogy cannot be said to be tenable, for many centuries it was the only one that prevented the atomic hypothesis from being chimerical. All the same, an elaborate theory was soon developed.

In order to explain nature's infinitude of forms, Leucippos postulated that the atoms were infinite both in number and in variety of shapes. A special reason for not limiting the number of shapes was his inability to find any particular shapes that seemed appropriate for atoms. Likewise he failed to discover any proper motions of the atoms; hence, he concluded that they could move in any direction. The celebrated example of the sun and the motes depicting atomic chaos is believed to have been given first by the early atomists although Lucretius' account[5] is the only one extant: "Of this truth, which I am telling, we have a representation and picture always going on before our eyes and present to us: observe whenever the rays are let in and pour the sunlight through the dark chambers of houses: you will see many minute bodies in many ways through the apparent void mingle in the midst of the light of the rays, and as in never-ending conflict skirmish and give battle combating in troops and never halting, driven about in frequent meetings and partings." Some moderns have taken this indefiniteness as an implication that chance was inherent in his system, because a similar postulate of a random distribution is basic in statistics to-day. But this was far from beng true. Indeed, Leucippos, was the first to enunciate what Leibniz later emphasized as his *raison suffisant* or "there is a sufficient reason for every happening" and what Swann[6] recently called the "intelligent design" of the universe. Of course, the atoms jostled one another in their motions so that entanglements inevitably ensued on account of the variety of shapes. These clusters became larger and larger until ordinary matter resulted. In these formations three ill-defined possibilities were recognized as is illustrated by the figures of a square and a parallelogram in Fig. 1.

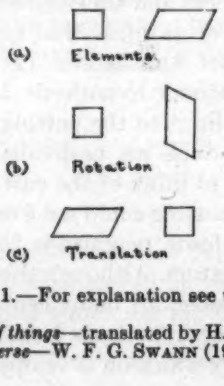


Fig. 1.—For explanation see text.

[5] *Lucretius—On the nature of things*—translated by H. A. J. MUNROE (1919) Book II.
[6] *The architecture of the universe*—W. F. G. SWANN (1934) 401.

That such arrangements were highly fanciful is not to be denied. And yet, what about the hooked atoms of John Bernoulli and of the nineteenth-century chemists? Certainly all these elaborate theories of the structure of matter were presumptuous before the atomic hypothesis had met an *experimentum crucis* such as Einstein's equation for Brownian movements later offered.

Greek speculation became rampant in the subsequent history of atomism. Democritos of Abdera (c.460–370 B.C.), changing only a few minor matters, discussed in even greater detail the various types of arrangement so that he was finally able to give an explanation of sensation itself on this basis. And then using this as the foundation for a theory of knowledge and of ethics, as well as for the usual cosmology, he formulated a complete philosophic system. The distinctive physical feature of his type of atom was its unrestricted size, e.g., an atom could be as large as a house. In other words, there was an infinity of both shapes and sizes. From our viewpoint, however, the significance of Democritos' work can be judged best from two statements of his own. In the first place he reäffirmed the dictum of Melissos that "nothing is created out of the non-existent, or is destroyed into the non-existent." This is the gist of our modern principle of continuity, which has so many special forms, e.g., Kirchhoff's first law for an electric circuit. He stressed also that absolute determinism that follows logically any mechanical representation of the universe. "By necessity are foreordained all things that are and are to come." Any failure to trace the mechanical process results merely from ignorance. So he noted the possibility of a plurality of causes for a final state that alone is observed, e.g., here is the earth, what is its origin? But the ethical implications of his system already foreshadowed the approaching abandonment of the study of natural philosophy for its own sake—an ironical turn, for the "laughing philosopher" scorned utilitarian motives.

Greek atomism culminated in the work of Epicuros[7] of Samos (c. 341–270 B.C.), whose system has been carefully preserved in that immortal poem of Titus Carus Lucretius (c.98 or 95–55 B.C.), *De Rerum Natura*. Once more the reality of sensation was made the *sine qua non* of all knowledge. Indeed, empiricism was extended to a rejection of the infinite divisibility of matter. For the strength of materials did not seem to warrant the inevitable destruction that the constant breaking up of matter would cause. Epicuros proceeded to modify the atomic theory by assigning another property to the atom

[7] *The Greek atomists and Epicurus*—CYRIL BAILEY (1928).

—weight. We are to understand this, not as technically differentiated from inertia, but as vulgarly used for either. It was this weight which caused the atoms to move, not promiscuously throughout space, but all downward with the same speed. Yet, how could such a rain of atoms bring about the clustering entanglements? Occasional swervings had to be allowed so that collisions could take place. As a matter of fact, even upward motion could be realized by the squeezing of a light atom in contact with two heavy swerving ones (cf. Fig. 2). It

Fig. 2.—For explanation see text.

is interesting to note that the speed of the atoms was supposed to be invariable. (This same assumption was made by Rudolph Clausius [1822–1888] in his kinetic theory, notwithstanding his recognition of its invalidity owing to collisions.) The notion of swervings, for which no reason was assigned, appears strangely arbitrary in a deterministic system. And yet, it was not an accidental choice. On the contrary, it was a deliberate attempt to permit freedom of the will in a system which had only a single hypothesis—the atom. And again we see the increasing influence of ethical ideals upon physical ideas. This relationship has never been severed although it is most common now in an inverted form, i.e., physical laws are sometimes regarded as cabalistic expressions of ethical principles. One recalls the popular philosophies of freedom which found support in the spontaneity of Bohr's electronic transitions—not to mention the mysticism[8] concomitant to Heisenberg's "uncertainty principle." Truly the relation between swerving atoms and wavering ethics is as suggestive to-day as when it allowed for Epicurean delights and for Lucretius' suicide.

Epicuros retained Leucippos' view that atoms did not lose their speed while in an entangled array. He explained the usual varying velocities by a preponderance of atoms in a certain direction of motion—a sort of balancing effect. For example, a body, consisting of 100 atoms all moving to the left momentarily and of 50 more all moving to the right momentarily, would move to the left with less speed than that common to the atoms. (It is difficult to apprehend this in our modern terms of force and inertia.) The possibility of rest resulting from a combination of moving particles is illustrated by

[8] *The nature of the physical world*—A. S. EDDINGTON (1928) 332. *The mysterious universe*—JAMES JEANS (1930) 31.

Lucretius' classical picture[6] as follows: "Thus often the woolly flocks as they crop the glad pastures on a hill, creep on whither the grass jewelled with fresh dew summons and invites each, and the lambs fed to the full gambol and playfully butt; all which objects appear to us from a distance to be blended together and to rest like a white spot on a green hill." There is still another fact which should be added to our description of Epicuros' atomism. He rejected Democritos' atoms of unlimited size. Furthermore, he postulated only a finite number of shapes for a given magnitude. Just as an atom was conceived to be the physical limit of divisibility, so, too, a surface was to be regarded as having a minimum part that could not be divided. And all surfaces had to consist of an integral number of such parts. To use Brieger's illustration, suppose the minimum part is a square. Now consider an atom made up of three cubes, of which each face is such a minimum square. Then there are only two possible shapes for this type of atom (cf. Fig. 3). (The condition is that each surface

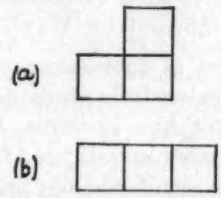


Fig. 3.—For explanation see text.

of the atom must consist of an integral number of these squares.) Thus the limit of size itself sets a limit to the number of shapes. A final remark, the atoms of air were looked upon as being very loosely arranged; those of a liquid were regarded as more permanently restrained by an outside shell; those of a solid were believed to be closely interlocked. Our modern view would show a similar picture.

The atomism of the Greeks can hardly be said to be like that of the present even though certain conclusions appear identical. Indeed, we have given the above description to emphasize the fact that any such notion can be the result only of gross misconceptions. We are impressed, however, by the similarity between the operation of the human mind then and now. The same thought-mold is evidentally essential to any given theory, whether it is speculative or experiential in origin. For principles we deem peculiar to our modern scientific world are found to be the underlying hypotheses of Greek surmises. But what stands out unique in their view of nature is the grandeur

of the possibility of a unified explanation. This intellectual vision looms far above the shadowy horizons of Egypt, Chaldea and India. Again and again, their esthetic desire for a coherent whole asserted itself in philosophic systems, which we find puzzling without access to the scaffolding used in the constructions. But even to-day they tower above our own world to remind us that mankind is still in quest of unity.[9] Somehow the sober light following the flushed dawn of enthusiasm has revealed to us that metaphysics (*μετά φυσικά*) must always come *after physics* and that physics itself is not too amenable to a unified rationalization. But with many of the Greek hypotheses coloring our scientific fabric and with many of their threads yet to be unentangled we, too, seek to weave a universal design.

[9] *A survey of physics*—MAX PLANCK (*The unity of the physical universe* is the title of one of a collection of essays).

PHYSICS.—*Pressure-volume-temperature relations for six oils.*[1] RICHARD B. DOW, Research Laboratory of Physics, Harvard University. (Communicated by MAYO D. HERSEY.)

The physical properties of lubricating oils at high hydrostatic pressures have not been extensively studied. The viscosity of oils at high hydrostatic pressures has, however, been studied[2,3,4] at this laboratory and is being further investigated for it has long been recognized that viscosity is the significant physical property in thick film lubrication. The study of the thermodynamic properties of oils under pressure has been neglected except for the pressure-volume data that were obtained by Hyde[5] at one temperature. It is well known that the pressure-volume relations must be observed at more than one temperature in order that a thermodynamic analysis be complete.

The present technical advances in the production of mineral oils wherein considerable attention is devoted to the chemical properties of crudes other than those of a paraffinic base, and the increasing use of the method of dimensional analysis[6] in predicting physical relations that may depend on the properties of lubricants, make desir-

[1] This investigation has been financed by the Special Research Committee on Lubrication, American Society of Mechanical Engineers, as a part of their research program and was carried out in this laboratory with Professor P. W. Bridgman's high pressure apparatus. It is a pleasure to acknowledge his interest and kindness as well as the coöperation of Professor Theodore Lyman. Received August 10, 1934.

[2] M. D. HERSEY. This JOURNAL 6: 525. 1916.

[3] M. D. HERSEY and H. SHORE. Mech. Eng. 50: 221. 1928.

[4] R. V. KLEINSCHMIDT. Trans. A.S.M.E., APM-50-4. 1928.

[5] J. H. HYDE. Proc. Roy. Soc. A 97: 240. 1920.

[6] M. D. HERSEY. This JOURNAL 23: 297. 1933. Also Proc. World Petroleum Congress, London: 1934, p. 389.

able at this time a survey of some of the thermal functions of typical oils that are used in lubrication. While it is realized that a complete understanding of these thermal properties, such as one obtains for a pure, comparatively simple liquid, will probably never be attained, it is believed that it would be of interest to have some of them recorded and a comparison made with the corresponding properties of simpler liquids.

This investigation presents the pressure-volume-temperature data obtained on six oils up to hydrostatic pressures approaching apparent solidification at temperatures of 25°, 40°, and 75°C, and includes a discussion of the thermodynamic characteristics[7] which are derivable from the fundamental data.

THE METHOD AND APPARATUS

The isothermals at the three temperatures were determined by the sylphon method of Bridgman.[8] A liquid is sealed within the sylphon to which is attached a slide-wire and the sylphon, mounted in a suitable holder, is placed within a pressure chamber of conventional type.[9] When hydrostatic pressure is applied the change of volume is proportional to the change of resistance of the slide-wire which is part of an external potentiometer circuit.[10] Once the constants and the corrections of the sylphon are known, it is a simple matter to compute the relative volumes from the corresponding resistance measurements. The pressure is computed from the change of resistance of a manganin coil, and the temperature is the corrected thermometer reading of a thermostatically controlled water bath.

DESCRIPTION AND CHOICE OF OILS

The six oils used for this study were from various sources. The four light mineral oils of approximately equal viscosity at 30°C, but from different crudes, were obtained from the Atlantic Refining Company through courtesy of Dr. J. Bennett Hill. The following characteristics were furnished by Dr. Hill (Table 1).

The Pennsylvania oil was a distillate from a crude of the same name which had been percolated through clay to obtain the final color. The Mid-Continent was made from a distillate from a mixed base

[7] The thermodynamic characteristics of a substance, whose state is defined by t and p, are completely determined when the following are known: (1) $(\partial v/\partial t)_p$ and $(\partial v/\partial p)_t$ over an extended range of t and p; (2) v at an arbitrary t and p within the range of (1); and (3) C_p along some line not an isothermal, t is the thermodynamic temperature.

[8] P. W. BRIDGMAN. Proc. Amer. Acad. 66: 185. 1931.

[9] P. W. BRIDGMAN. *The physics of high pressure*, Chap. 2: Macmillan. 1931.

[10] P. W. BRIDGMAN. Proc. Amer. Acad. 56: 64. 1921.

TABLE 1.—PHYSICAL CONSTANTS OF OILS[11]

Type of Oil	Gr. A.P.I. 60°F	Saybolt Univ. Vis. 100°F	Saybolt Univ. Vis. 210°F	V.G.C.	Flash °F
Pennsylvania	31.1	145	42.0	0.818	385
Mid-Continent	29.2	137	40.2	0.832	375
Renown Engine	25.7	145	39.1	0.856	375
Gulf Coast	23.7	130	38.0	0.872	320

Texas crude by pressing, redistilling, acid treating and percolating through clay. The Gulf Coast was a distillate from a Texas crude, acid treated and neutralized.

The remaining samples were fixed oils, lard and sperm, having somewhat greater viscosity at 30°C. The lard oil was a clear, translucent product from a local source while the sperm oil was furnished by Mayo D. Hersey from his collection of oils tested by Hyde[5] at the National Physical Laboratory some fourteen years earlier.

It is well known that the principal constituents of Pennsylvania oil are the paraffines, C_nH_{n+2}, and that the Gulf Coast crudes consist mainly of the napthenes or cycloparaffines, C_nH_{2n}. The fatty oils are composed of glycerides and a mixture of acids belonging to the series $C_nH_{2n+1}\cdot COOH$.

It would appear that the above choice of oils is such that any significant structural features related to volume would be exhibited at high pressures. This reasoning, more or less speculative, is based on the numerous results that Bridgman[8] has obtained with pure liquids. For example, he has shown that the liquids of the methane series have considerably different compressibilities from those of the benzene series. Hyde's work showed that the compressibilities of oils of wide difference in viscosity at 40°C differ slightly, but his results were insufficient to give all the information one would like and, also, his choice of mineral oils was not the one best suited to exhibit the relation between the structural features and the molecular volume of the different basic crudes when subjected to high pressures.

COMPUTATION OF DATA AND OTHER FUNDAMENTAL QUANTITIES

Volumes.—The fundamental data consist of the volumes of oils at definite pressures and temperatures. These data are collected in Table 2. All further information of thermodynamic interest can be

[11] The abbreviations used in Table 1 have the following meanings: *Gr. A.P.I.*, The American Petroleum Institute's specific gravity scale; *Saybolt Univ. Vis.*, the viscosity as indicated by the Saybolt Universal Viscosimeter; *V.G.C.*, the viscosity-gravity constant (J. B. HILL and H. B. COATS, Ind. Eng. Chem. 20: 641. 1928) to indicate the degree of paraffinicity; *Flash*, the A.S.T.M. flash point or temperature at which the vapor of the oil ignites.

TABLE 2.—Relative Volumes

Pressure kg/cm²	25°	40°	75°	25°	40°	75°
	Pennsylvania Oil (ρ_{15}=0.8524)			Mid-Continent Oil (ρ_{15}=0.8663)		
1	0.9901	1.0000	1.0178	0.9894	1.0000	1.0197
50	0.9869	0.9966		0.9861	0.9964	
100	0.9839	0.9934		0.9832	0.9930	
250	0.9752	0.9841	1.0040	0.9746	0.9838	1.0038
500	0.9632	0.9711	0.9908	0.9625	0.9704	0.9895
750	0.9529	0.9599	0.9786	0.9526	0.9594	0.9768
1000	0.9440	0.9504	0.9672	0.9441	0.9497	0.9659
1250		0.9418	0.9572		0.9412	0.9561
1500		0.9340	0.9485		0.9336	0.9476
2000		0.9196	0.9330		0.9199	0.9329
2500			0.9196			0.9204
3000			0.9082			0.9094
3500			0.8983			0.8995
4000			0.8891			0.8900
	Gulf Coast Oil (ρ_{15}=0.8937)			Renown Engine Oil (ρ_{15}=0.8842)		
1	0.9902	1.0000	1.0182	0.9905	1.0000	1.0177
50	0.9868	0.9966		0.9874	0.9967	
100	0.9838	0.9935		0.9845	0.9936	
250	0.9757	0.9845	1.0041	0.9761	0.9847	1.0037
500	0.9643	0.9714	0.9909	0.9642	0.9723	0.9907
750	0.9544	0.9605	0.9788	0.9544	0.9615	0.9791
1000	0.9457	0.9512	0.9678	0.9461	0.9522	0.9687
1250		0.9431	0.9578		0.9437	0.9589
1500		0.9354	0.9492		0.9359	0.9504
2000		0.9218	0.9342		0.9219	0.9352
2500			0.9216			0.9226
3000			0.9106			0.9115
3500			0.9010			0.9018
4000			0.8925			0.8931
	Lard Oil (ρ_{15}=0.9009)			Sperm Oil (ρ_{15}=0.8945)		
1	0.9902	1.0000	1.0190	0.9894	1.0000	1.0227
50	0.9872	0.9965		0.9864	0.9966	
100	0.9841	0.9936		0.9835	0.9934	
200				0.9781	0.9876	1.0099
250	0.9763	0.9850	1.0051			
300				0.9730	0.9818	
400				0.9685	0.9768	
500	0.9647	0.9721	0.9921		0.9722	0.9925
750	0.9550	0.9615	0.9800		0.9618	0.9794
1000	0.9461	0.9523	0.9697		0.9525	0.9684
1250	0.9377	0.9440	0.9603		0.9437	0.9591
1500	0.9299	0.9366	0.9522			0.9510
2000		0.9229	0.9374			0.9368
2500		0.9111	0.9240			0.9241
3000			0.9120			0.9127
3500			0.9016			0.9021
4000			0.8927			0.8926

computed from them, assuming the specific heat at constant pressure for atmospheric pressure to be known. The calculations were made in the following manner: The equivalent slide-wire resistances were plotted against pressure on large graph paper for the temperatures 25°, 40°, and 75°C, and smooth curves drawn. The changes of volume were directly computed from the corrected changes of resistance, read off at even pressure intervals, by applying the various conversion and correction formulae.

For these computations and those which follow, the nomenclature adopted by Bridgman[12] has been followed. The actual losses of volume in cm^3 were computed from the volume at atmospheric pressure at 40°C taken as unity. This method of expressing the data aids in a quicker understanding of Table 2 and simplifies the calculation of thermal quantities; thus, in computing the compressibility, $(\partial v/\partial p)_t$ was used instead of the more common form $(1/v_0)\ (\partial v/\partial p)_t$. In Table 2, ρ_{40} denotes the density at 40°C in grams/cm^3.

The densities at atmospheric pressure were determined at three temperatures by the use of a specific gravity bottle, for two reasons, instead of relying on the sylphon measurements alone. First, the measurement of the volume of the sylphon at atmospheric pressure and 75° could not be made because of danger of the sylphon expanding beyond a safe limit. This made it necessary that the thermal expansion between 40° and 75° be known in order for the pressure-volume data at the highest temperature to start at atmospheric pressure without extrapolation. Consequently, the volumes in Table 2 at atmospheric pressure and 75° are those volumes determined by specific gravity measurements. Second, knowing the expansion between 25° and 40° as the result of an independent measurement, the expansion between the same two temperatures as found by the sylphon method could be checked. The two determinations for thermal expansion differed by not more than 0.2 per cent.

Compressibility, Thermal Expansion, Specific Heat.—The compressibility was determined from the pressure-volume curves at constant temperature as the average compressibility over small ranges of the curves where departures from linearity were not important. The thermal expansion was similarly derived. The variation with pressure of the specific heat at constant pressure, might be calculated from the data given, but it is believed that nothing is to be gained from it

[12] P. W. BRIDGMAN. Proc. Amer. Acad. 49: 100. 1913; and also Chap. V of *The physics of high pressure.*

for the time being. Twelve pure liquids examined in this respect by Bridgman[12] showed such a bewildering variety of curves that he considered speculation hopeless as to the cause of all the variations.

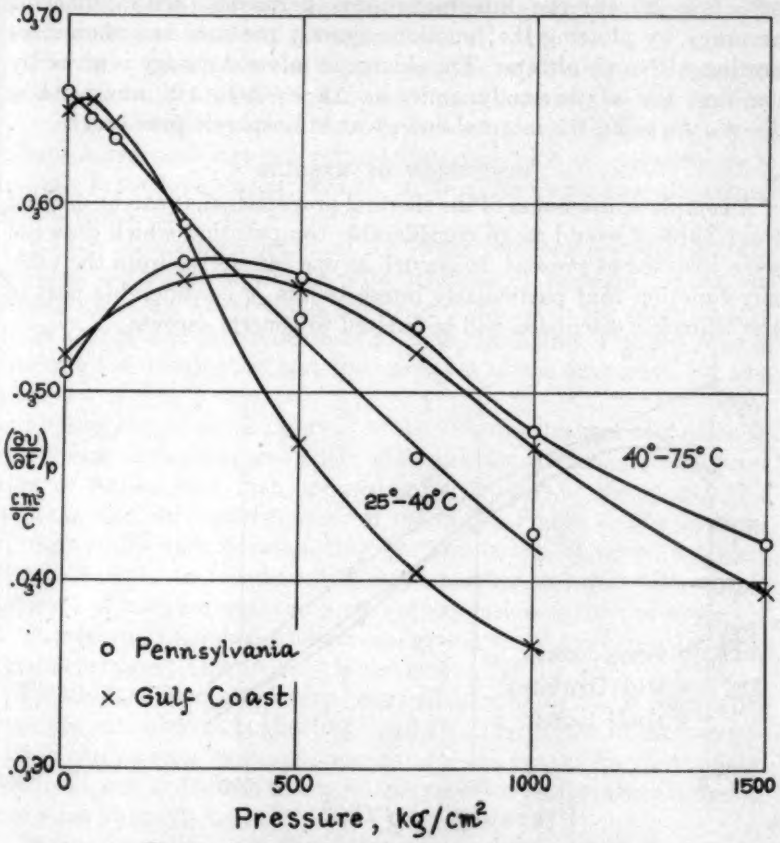


Fig. 1.—Average thermal expansion against pressure.

Thermodynamic Functions.—The functions to be considered are: the *pressure coefficient*, i.e., coefficient of pressure change with temperature at constant volume, *work of compression*, *heat of compression*, and *change in internal energy*. If the *pressure coefficient* $(\partial p/\partial t)_v$ is constant along some line of constant volume which cuts three isothermals at temperatures t_1, t_2, and t_3, the ratio of pressure differences $(p_3-p_2)/(p_2-p_1)$, where in each case, the pressure at the same volume is read off its respective isothermal, is equal to the ratio $(t_3-t_2)/$

$(t_2 - t_1)$. The pressure coefficient will be discussed in this sense. The work of isothermal compression was calculated by the integral $\Delta W = \int -p(\partial v/\partial p)_t dp$, and the corresponding heat of compression by $\Delta Q = \int t(\partial v/\partial t)_p dp$; the integration was performed with sufficient accuracy by plotting the functions against pressure and then integrating with a planimeter. The change in internal energy is given by the first law of thermodynamics as $\Delta E = -\Delta Q + \Delta W$ where $\Delta E = E - E_0$, E_0 being the internal energy at atmospheric pressure.

DISCUSSION OF RESULTS

A complete discussion of the thermal properties that can be derived from Table 2 would mean considerable computation which does not seem justified at present. Inasmuch as one can derive from the table any function that particularly interests him, a considerable part of the following discussion will be limited to general aspects.

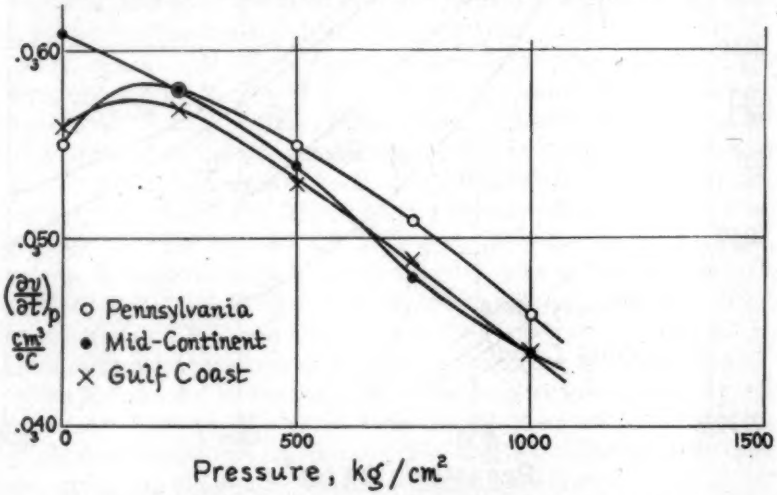


Fig. 2.—Average thermal expansion 25°–75°C against pressure.

Relative Volume, Compressibility, and Thermal Expansion.—A brief inspection of Table 2 shows that the relative volumes do not vary greatly for the six oils. Consequently, the compressibilities and thermal expansions of the different oils are not greatly different.

On computing the compressibility for the Pennsylvania sample at 40°, it was found that the compressibility at 1000 kg/cm² was 35.5×10^{-6}, or about one-half its initial value of 68×10^{-6}. This places the compressibility of the oil at approximately the middle of the range

from the high value of n-pentane to the low value of glycerine. This conclusion applies equally well for the remaining oils. As regards the effect of temperature on the compressibility, the six oils behave as normal liquids in that the compressibility increases slowly with temperature at constant pressure.

For most substances the thermal expansion $(1/v_0)(\partial v/\partial t)_p$ increases with temperature; $(\partial^2 v/\partial t^2)_p$ is positive and decreases as the pressure is raised. The behavior of the oils is not normal in this respect at atmospheric pressure; the volume increases with temperature more rapidly in the lower range from 25° to 40°. This means that the second derivative is negative.

At the higher pressures and the lower temperature interval, the average expansion decreases with increase of pressure for all oils except the Gulf Coast which shows an increase in the range from 1 to 50 kg/cm² and then a decrease at higher pressures. Figure 1 reveals the order of magnitude and the variation of the expansion for two oils.

For the temperature interval 40° to 75°, the thermal expansion in every case changes anomalously with pressure; increasing with pressure to 300 kg/cm², then decreasing for the rest of the range. This effect is also illustrated for two of the oils in Figure 1. The reversal of sign of $\partial^2 v/\partial t \partial p$ is interesting for this is not observed for pure liquids.[12] Since the coefficient is much smaller to begin with in this interval of temperature, the curves of expansion against pressure for both intervals of temperature cross, giving the same expansion at a certain pressure. This pressure is also close to 300 kg/cm².

Finally, the average thermal expansion remains to be considered over the entire range between 25° and 75°. The results of the computation can be seen by examining the pressure curves for three of the oils in Figure 2. The expansion in this range of temperature is anomalous for Pennsylvania and Gulf Coast oils.

There seems little likelihood for an adequate explanation of the complications in the thermal expansion at high pressures. Bridgman[12] pointed out in 1913 the need for considering the shapes and orientations of the molecules and their assemblages in order to get even a simple picture of some of the complicated effects of expansion in pure liquids at high pressures. Undoubtedly, the effects of shape and orientation play important parts in the complications, but the molecular groups or aggregates are so complex in any oil that the significance of structure is obscured. For example, one would expect that the expansion of an oil of naphthenic base would be more com-

plicated than the expansion of one of paraffinic base, because in the latter the chain compounds should show less tendency for haphazard arrangement under pressure and the regularity of orientation should increase with pressure. For the oil of ring-type molecules, the resulting change in orientation with change of pressure would be expected to be less regular because of the less orderly interlocking between groups of molecules. However, these speculations are not substantiated by the data of this paper. There seems to be no clear effect of structure on the thermal expansion. While the pressure-expansion curve for the interval 25°–40° appears to have a more uniform slope in the case of the Pennsylvania oil than for the Gulf Coast oil, the same curve if drawn for lard oil reveals a complexity comparable to that observed for the Gulf Coast oil. The expansions for paraffinic and fatty oils have smaller changes with pressure than the expansions for naphthenic and mixed-base oils but the differences are small.

Work and Heat of Compression; Change in Internal Energy.—The work and heat of compression were calculated for the Pennsylvania sample and curves of these functions against pressure were examined. The curves are similar in shape to those for pure liquids[12]. The curve for the work done in compressing the oil starts out in a normal way as the pressure is increased and the work done in the first 2000 kg/cm² is about half that of a normal liquid. The heat of compression increases uniformly with the pressure and amounts to about 1.5 kg.m. against 3 or 4 kg.m. for pure liquids.

The change in internal energy of these oils is small because of the limitation of the pressure range imposed by the relatively low freezing pressures. The ΔQ and ΔW curves are normal in the pressure range which is limited to 2000 kg/cm² at 40°, and the ΔE curve varies in such a way that ΔE decreases uniformly with increase of pressure under the same conditions.

The ratio $\Delta E/\Delta W$ is of interest because it offers a means of estimating the work done by the attractive forces between the molecules

TABLE 3.—RELATIVE VALUES OF THE RATIO $\Delta E/\Delta W$ AT 40°C

Liquid	$\frac{(\Delta E/\Delta W)_{1000}}{(\Delta E/\Delta W)_{2000}}$	$\frac{(\Delta E/\Delta W)_{1000}}{(\Delta E/\Delta W)_{3000}}$
Acetone	1.92	1.84
Pennsylvania oil	1.84	1.50
Ethyl alcohol	1.65	1.84
Carbon disulphide	1.62	1.83
Ether		1.19

when the substance is compressed. This ratio has been computed at several pressures for the Pennsylvania oil and a few pure liquids. The results are expressed in Table 3 as the change of $\Delta E/\Delta W$ produced by pressure.

Pressure Coefficient.—Bridgman[8] has proved that $(\partial p/\partial t)_v$ cannot be a function of volume alone as had often been considered to be the case. By evaluating the ratio of pressure differences as already explained, he found that instead of the ratio equaling 0.90, which should be the case if the coefficient is a function of volume at 0°, 50°, and 90°, it varied considerably with all the pure liquids at low pressures. At higher pressures, the departures from 0.90 were much greater.

In the following table the ratio $(p_3-p_2)/(p_2-p_1)$ is listed for five oils. The range of volume is unavoidably small. The pressures p_1, p_2, p_3, for different relative volumes were read off the isotherms for 25°, 40°, and 75°, respectively. The ratio $(p_3-p_2)/(p_2-p_1)$ should thus equal 2.33 for all volumes if the pressure coefficient is a function of volume alone.

TABLE 4.—EVALUATION OF THE RATIO $(p_3-p_2)/(p_2-p_1)$

Oil	Rel. Vol.	Pressure Ratio	Rel. Vol.	Pressure Ratio	Rel. Vol.	Pressure Ratio
Pennsylvania	.990	2.42	.980	2.58	.945	2.65
Mid-continent	.988	2.50	.980	2.09	.945	2.72
Gulf Coast	.990	2.21	.980	2.40	.945	2.36
Renown	.992	2.16	.980	2.33	.945	2.53
Lard	.991	2.50	.980	2.45	.945	2.69
Lard	.920	1.76				

The departures of the Pennsylvania and Renown oils from 2.33 increase with pressure. The Mid-continent and lard oils show more irregularity.

Remarks on Sperm Oil.—The change in density of sperm oil with pressure has been computed by Hyde.[5] As the oil used in the present work was a sample of the same oil that had been tested by Hyde, it was hoped that a means of comparison of the two investigations would be had. The density at atmospheric pressure given by Hyde was over 3 per cent less than the value found here, being 0.866 against 0.895. This is not surprising when one considers that the oil has probably oxidized during the interval of fourteen years. It is interesting, however, to observe that when the pressure-density curves are drawn for both tests, the slopes are approximately equal, hence the compressibilities computed from them differ only by the initial value taken for the density.

CONCLUSION

The relative volumes at three temperatures have been recorded at pressures up to those approaching the apparent solidifying pressures for six oils of different composition. It has been found that the volumes and the derived thermal properties, in general, are similar for all the oils. But of the variations determined the thermal expansion varies the most with pressure and temperature, and in a manner contrary to its behavior for pure liquids at low pressures.

It would seem desirable to obtain more detailed information about the thermal expansion as well as data on the viscosity and thermal conductivity at high pressures. In order to study the thermal effects at high pressures in more detail, one of the mineral oils has been fractionated and the present investigation is being continued for some of the individual cuts from this oil.

CHEMISTRY.—*p-Fluorophenacyl alcohol and some of its esters.*[1]

RAYMOND M. HANN and J. P. WETHERILL, Washington, D.C.
(Communicated by FREDERICK H. GOLDMAN.)

Judefind and Reid,[2] in their study of p-halegon, substituted phenacyl bromides as reagents for the separation and identification of acids, have indicated the superiority of the halogen compounds over the unsubstituted phenacyl bromide because of the lower solubility of the resulting halogenated esters.

A search of the available literature indicates that a p-fluorophenacyl halide has not been studied in this connection, and the purpose of the present study was to isolate a suitable fluorine compound and test its applicability as a reagent. The study has revealed that p-fluoro-ω-chloroacetophenone may be readily prepared in large yield by the Friedel Crafts' reaction. The fluorophenacyl esters so far obtained possess no advantage over other already described p-halogen esters, and the original cost of fluorobenzene mitigates against their preparation.

Incidental to the preparation of the esters, p-fluorophenacyl alcohol (also known as p-fluorobenzoyl carbinol) has been obtained to complete the list of possible p-halogenated phenacyl alcohols.

EXPERIMENTAL

p-Fluorophenacyl chloride (*ω-chloro-p-fluoroacetophenone*).—To a constantly stirred suspension of 75 g. of anhydrous aluminum chloride

[1] Received October 23, 1934.
[2] Jour. Amer. Chem. Soc., 42: 1043. 1920.

in 150 cc. of carbon disulfide and 48 g. of fluorobenzene at room temperature, 56 g. of chloroacetyl chloride were added dropwise during the course of 1 hour. The reaction mixture was then gently refluxed for six hours, during which time it assumed a yellow color, hydrochloric acid gas was evolved, and a somewhat darker colored heavy oil separated. It was cooled and poured into a suspension of 90 g. of concentrated sulfuric acid in finely crushed ice, the resulting crystalline precipitate filtered off, and the residual carbon disulfide separated and evaporated to yield a further crystalline deposit. The combined solids were recrystallized from two parts of 95 per cent alcohol, the substituted phenacyl chloride obtained weighing 68.4 g. (79 per cent, based on fluorobenzene). Appreciation is expressed to H. P. Newton for assistance in carrying out this synthesis.

p-Fluorophenacyl chloride crystallizes in brilliant, glistening large plates, melting at 48°C. to a clear oil without decomposition. Its vapor has an intense lachrymatory action, and in warm weather it is volatile enough to cause severe discomfort when handled in ordinary manipulations.

Anal. Calcd. for C_8H_6OClF: Cl, 20.6. Found, 20.5.

p-Fluorophenacyl acetate.—A solution of 4 g. of p-fluorophenacyl chloride, 3 g. of fused sodium acetate and 0.5 cc. glacial acetic acid in a mixture of 5 cc. water and 20 cc. 95 per cent alcohol was refluxed for 1 hour. On cooling, alcohol in small amounts was added to prevent clouding, and after several days the acetate crystallized. Yield 3.9 g. (87 per cent).

p-Fluorophenacyl acetate crystallizes in glistening colorless scales from 60 per cent alcohol. It melts at about the same temperature as the chloride; namely, at 48.5° to 49.0°, but upon admixture with the halogen compound it liquefied.

Anal. Calcd. for $C_{10}H_9O_3F$: F, 9.7. Found, 9.5. Saponification equivalent 196.1. Found, 194.2.

p-Fluorophenacyl alcohol.—A suspension of 1 g. of p-fluorophenacyl acetate and 0.6 g. of washed barium carbonate in 50 cc. of water was refluxed for 1 hour; the acetate, an oil initially, gradually disappeared. The warm reaction mixture was filtered through char, and upon cooling the alcohol crystallized in colorless elongated plates melting at 114°C. in a yield of 0.7 g. (90 per cent). The melting point was unchanged upon recrystallization from 10 cc. of hot water. The acetate was regenerated by treatment with acetic anhydride.

Anal. Calcd. for $C_8H_7O_2F$: F, 12.3 Found, 12.1.

p-Fluorophenacyl nitrobenzoates.—A solution of 1.2 g. of nitro-

benzoic acid, 5.9 cc. of 1N. sodium hydroxide and 1 g. of p-fluorophenacyl chloride in 20 cc. of 95 per cent alcohol was refluxed for 1 hour and the reaction product obtained on cooling or by precipitation with small amounts of water. The esters may be readily recrystallized from 95 per cent alcohol.

p-Fluorophenacyl-o-nitrobenzoate crystallizes in very slightly yellow microscopic needles, melting at 74.5°C. to a clear oil.

Anal. Calcd. for $C_{15}H_{10}O_5NF$: nitrogen, 4.6. Found, 4.5.

p-Fluorophenacyl-m-nitrobenzoate separates in colorless glistening needles, melting at 105°C. to a clear colorless oil.

Anal. Calcd. for $C_{15}H_{10}O_5NF$: nitrogen, 4.6. Found, 4.5.

p-Fluorophenacyl-p-nitrobenzoate crystallizes in slightly yellow needles, melting at 134°C. to a clear oil.

Anal. Calcd. for $C_{15}H_{10}O_5NF$: nitrogen, 4.6. Found, 4.7.

SUMMARY

p-Fluorophenacyl alcohol and several of its esters have been prepared and described.

PHARMACOLOGY.—*The nitrite-thiosulphate combination as a remedy for cyanide poisoning in sheep.*[1] H. BUNYEA, J. F. COUCH, and A. B. CLAWSON, Bureau of Animal Industry.

In a former paper[2] the results of experiments with remedies for cyanide poisoning in sheep and cattle were reported. It was found that, of the remedies tried, a combination of sodium nitrite and sodium thiosulphate[3] was the most effective for cattle. The combination was not used on sheep at that time, but the results of the cattle experiments left little doubt that it would also prove to be the most effective remedy in the case of poisoned sheep.

The experimental methods used were the same as those already reported[2] and do not need extended repetition here. The cyanide was administered *per os* as potassium cyanide solution, freshly prepared, and the remedies were injected intraperitoneally, using 10 per cent solutions for the smaller doses and 20 per cent for the larger.

The results are given in Table I. Twenty-two experiments were performed with 18 animals of which 13 died. The doses were varied beginning with 2 m.l.d. calculated according to the figure previously reported for the m.l.d. (2.315 mg. per kg.), and rising gradually to 3.5 m.l.d. Table 2 is an analysis of these data and shows the effectiveness of the remedy against the various doses.

[1] Received November 1, 1934.
[2] This JOURNAL 24: 369–395. 1934.
[3] This remedy was first suggested by E. Hug., C.r.Soc. Biol. 114: 711–714. 1933.

TABLE 1.—NITRITE-THIOSULPHATE AS A REMEDY FOR CYANIDE POISONING IN SHEEP

Date	Sheep	Weight	Dose	Time from drench—			Remedy		Effect
				to first symptoms	to collapse	to giving remedy	Sodium nitrite	Sodium thiosulphate	
1934	No.	kg.	m.l.d.	min.	min.	min.	g.	g.	
May 8	1111	49.9	2	1	2.5	5.5	1	1	Survived
9	1113	50.8	2.25	1	1.5	2.5	1	2	Survived
8	1244	43.5	2.5		1.5	3	1	2	Died
9	1111	49.9	2.5	0.5	2	4	1	3	Survived
8	1113	50.8	2.5		1	2	1	2	Survived
15	1111	49.9	2.75	0.5	1.5	2.5	1	3	Survived
15	1113	50.8	2.75	1	1.5	2	1	3	Survived
23	1465	29.9	2.75	1	1.25	6	1	3	Died
23	1456	29.5	2.75	1	1	5.5	1	3	Died
23	1459	35.8	2.75	0.75	1.5	15	1	3	Survived
8	11730	38.1	3	1	1.5	3	1	2	Died
8	1241	34.5	3	1	1	2.5	1	2	Died
Aug. 30	1507	36.2	3	1	2	2	3	2	Died
30	102A	32.6	3	1	1.5	1.5	1	2	Died
30	1578	40.35	3	1.25	1.25	1.5	1	4	Died
31	1556	37.2	3	1	1.5	1.5	2	2	Survived
Sept. 11	1561	42.6	3	1.5	4	4.5	2	3	Died
11	1560	37.2	3	1	1.5	2	2	3	Died
11	1572	35.8	3.5	1.5	2	2	2	3	Survived
11	1487	39	3.5	1.5	2	2	2	3	Died
11	1479	41.2	3.5	0.5	1.5	1.5	2	4	Died
11	1499	39.9	3.5	1	2	2	2	4	Died

It is plain that, if administered promptly, the remedy is reasonably effective against 2.75 m.l.d. of cyanide in sheep as against 2 m.l.d. in cattle. Of 5 sheep that received this large dose, three survived and two died. In the latter cases the remedy was withheld until the animals were in the gasping stage and thus the test of the remedy was very severe. One of the sheep that survived, No. 1459 was not given the remedy until 15 minutes after the completion of the drench. This animal was unusually resistant to the cyanide and after exhibiting early symptoms began to improve instead of becoming progressively worse. This condition persisted for some 12 minutes during which

TABLE 2.—EFFECTIVENESS OF THE REMEDY AGAINST VARYING DOSES OF CYANIDE

Dose m.l.d.	Number of animals	Survived	Died	Per cent survival
3.5	4	1	3	25
3	8	1	7	12.5
2.75	5	3	2	60
2.5	3	2	1	66
2.25	1	1	0	100
2	1	1	0	100

time the sheep rose to his feet and remained standing a few seconds. He then began to stagger, went down on the belly and exhibited the usual train of symptoms shown by the other cases. Administration of the remedy was now withheld until the sheep appeared to be in a condition similar to that of the other sheep 3 to 4 minutes after drenching.

In our work on cyanide poisoning we have occasionally found resistant animals that show irregular behavior during the course of the sickness. Two other cases of similar behavior were encountered recently which will be reported in another paper of this series. Aside from these cases the course of the sickness with the poisoned animals was similar to that already described.

THE EFFECT OF AN INCREASED DOSE OF SODIUM NITRITE

Since little was known about the proper dose of sodium nitrite for sheep the question arose whether a dose larger than 1 gram might not be more effective. Nitrites are themselves quite toxic and there would be a dosage above which the remedy might itself cause or contribute to the death of the animal.

TABLE 3.—TOXICITY OF SODIUM NITRITE INJECTED INTRAPERITONEALLY

Date 1934	Sheep No.	Weight kg.	Dose mg./kg.	Actual dose g.	Effect
Aug. 31	1471	31.7	47.3	1.5	Died
" 31	1479	41.2	48.8	2	Survived
" 30	1521	34.45	58	2	Died
" 31	1516	42.6	70.4[a]	3	Survived
" 31	1482	31.7	78.8	2.5	Died
" 31	1480	34.9	84.8	3	Survived
" 31	1490	41.7	95.9[a]	4	Died
" 30	1527	34.4	113.3	4	Died
" 30	1504	38.09	120.7	4	Died
" 30	1499	39.9	150.3	6	Survived
Sept. 5	1499	39.9	150.3	6	Survived
Aug. 30	1467	40.8	195.9	8	Died

[a] Plus 2g. of sodium thiosulphate.

As a preliminary measure several sheep were given varying doses of sodium nitrite intraperitoneally. The data are detailed in Table 3. It is apparent that the effect of sodium nitrite is quite variable since four of the animals poisoned survived doses larger than proved fatal with other sheep and one, No. 1499, on two occasions survived the second largest dose given although 6 sheep were killed by much

smaller doses and one died on one-third as much. Owing to the variability it was impossible to draw conclusions about the m.l.d. The symptoms exhibited by the sheep consisted of depression and accelerated respiration. In sheep No. 1521 the rate of respiration reached 148 per minute within 10 minutes after injecting the nitrite and in sheep No. 1504, 152 per minute. Two experiments were made to obtain evidence as to whether the simultaneous injection of sodium thiosulphate would influence the toxicity of sodium nitrite. In neither case was there any apparent antagonism between the two salts.

The experiments led to the conclusion that a one gram dose of sodium nitrite intraperitoneally is the safest for remedial use and two grams is the largest dose that should be administered and then only under exceptional circumstances.

There remained the possibility that in actual cyanide poisoning the toxic effect of the nitrite might be counteracted by the cyanide and warrant the use of larger doses of sodium nitrite. To test this possibility eight sheep were given 3 m.l.d. of potassium cyanide and 4 were given 3.5 m.l.d. by mouth and immediately upon collapsing were treated with varying doses of sodium nitrite combined with sodium thiosulphate. The results are summarized in Table 4.

TABLE 4.—EFFECT OF INCREASED DOSES OF SODIUM NITRITE

Dose m.l.d.	$NaNO_2$ g.	$Na_2S_2O_3$ g.	Number of animals	Survived	Died
3	1	2	3		3
3	1	4	1		1
3	2	2	1	1	
3	2	3	2		2
3	3	2	1		1
3.5	2	3	2	1	1
3.5	2	4	2		2

From these figures it is apparent that increasing the dose of sodium nitrite did not alter the final outcome of the poisoning.

SUMMARY

The combination of sodium nitrite and sodium thiosulphate protects with reasonable certainty against 2.75 m.l.d. of cyanide particularly when the remedy is administered promptly.

Increasing the dose of nitrite to 2 and 3 g. did not result in improvement while introducing an unfavorable element due to the toxicity of the nitrite itself.

Increasing the dose of thiosulphate may have resulted in some

improvement and does not, of itself, introduce another toxicity factor.

The nitrite-thiosulphate combination was definitely more effective with sheep than with cattle.

Doses of sodium nitrite above 95 mg. per kg. are likely to be fatal and above 50 mg. per kg. are dangerous. The safest therapeutic dose that can be recommended for cyanide poisoning is 1 g. intraperitoneally for a 75 to 90 pound (35 to 40 kg.) sheep and 2 g. is the largest dose that should be given.

PALEONTOLOGY.—Celliforma spirifer, *the fossil larval chambers of mining bees.*[1] ROLAND W. BROWN, U. S. Geological Survey. (Communicated by JOHN B. REESIDE, JR.)

The 1930 Smithsonian expedition, led by C. W. Gilmore to the Bridger Basin in southwestern Wyoming, brought back to the National Museum among its collection of fossils a handful of curious, solid objects (Fig. 3) that have remained unidentified. These specimens were found by George B. Pierce in surface material weathered from the lower strata of the fresh-water Bridger formation of upper Eocene age, about 6 miles southeast of Mountainview, Wyo., in sec. 18, T. 14 N., R. 14 W.

The natural size sketch (Fig. 3) illustrates several of the more perfect specimens. They average 2.7 centimeters in length by 1.2 centimeters in diameter. They are greenish gray to white in color, smooth, and round; but many are slightly flattened and bent like a bean; most show the effects of former breakage and partial collapse and now superficially resemble cracked but not disintegrated eggshells. The apex is a low dextral spiral of four or five turns making an inconspicuously scalloped and pitted groove. In some examples the apex is an almost flat spiral, in others the last turns form a narrow prominent blunt point.

Numerous sections disclosed no internal cellular structure or organic remains of any kind. The matrix of the unbroken specimens is calcite; that of the more or less broken specimens is calcite and greenish clay. It is clear that the calcite crystallized in a cavity, sometimes filling the cavity completely, sometimes leaving empty pockets to be filled or not with clay.

Speculation about these objects ranged from snake eggs to date seeds, on which latter probability they were referred to me for identification. A search of the literature and the seed collections, however,

[1] Published by permission of the Director, U. S. Geological Survey. Received October 30, 1934.

failed to develop any definite clues suggesting relationship to plants. Turning to animal fossils, I found that Scudder[2] had described and figured a mass of insect eggs under the name *Corydalites fecundum*. These eggs are minute, 2.6 millimeters long by 0.6 millimeter wide but, when enlarged to a size comparable with the Wyoming specimens, become somewhat like them. Nevertheless, the large size of the Wyoming specimens, it seems to me, effectively precludes their having been insect eggs.

The specimens compare best with material described and figured by Dall[3] from the "silex beds" of the Tampa formation (now regarded as of lower Miocene age) at Ballast Point, Tampa Bay, Fla. According to Dall, his Figure 4, Plate 24, which is almost identical with some Wyoming specimens, represents the burrow of a fossil limestone-boring bivalve mollusk, *Lithophaga nuda* Dall (his Fig. 7, Pl. 26). After an examination of these types and all the similar material in the National Museum collections from the "silex beds," I am of the opinion that a few may be molds of *Lithophaga* burrows; but with respect to those having the characteristic spiral apex, I demur. *Lithophaga* has no operculum, does not close its burrow, and possesses no other mechanism that would account for the origin of the spiral in the fossils.

There seems to be no question that the Wyoming and Florida specimens represent relics of the same type of organism, though the species may well be different, but not at present definitely separable. The Florida specimens (Fig. 1) differ from the Wyoming specimens chiefly as follows: They are composed of chalcedony and may be solid or partially solid with free water in the unfilled space, visible when the specimen is handled. They are somewhat shorter and stouter, and the apical spire in most cases is narrower and longer. They are found in sediments that were deposited in the marine or brackish water of an estuary or bay. These differences in structure, composition, and occurrence, fortunately for the argument, are not mutually exclusive and fatal, when it is remembered that the fauna of the "silex beds," besides some 300 marine and brackish-water mollusks, also includes 24 species of land and fresh-water shells.[4] Evidently land was close to the site of deposition of these beds. It seems

[2] SCUDDER, S. H. *The Tertiary insects of North America*. U. S. Geol. Survey Terr. Rept. 13: 139–153, *pl. 4, figs. 5–7, 13–16, 18–21, 23*. 1890.

[3] DALL, W. H. *A monograph of the molluscan fauna of the Orthaulax pugnax zone of the Oligocene of Tampa, Fla.* U. S. Nat. Mus. Bull. 90: 129, *pl. 24, fig. 4; pl. 26, fig. 7*. 1915.

[4] COOKE, C. WYTHE, and MOSSOM, STUART. *Geology of Florida*. Florida Geol. Survey Ann. Rept. 20: 82. 1929.

therefore that any explanation that presumes to account for the ultimate origin of these objects in one case must apply, perhaps with some slight modification, to the other also.

No identification seeming acceptable at the time, these specimens were temporarily set aside and did not claim attention again until August 27 of this year (1934). On that day, geological field work brought me to a locality one-half mile up Cove Creek from its mouth on the Weiser River, 9 miles east of Weiser, Idaho. There, on the

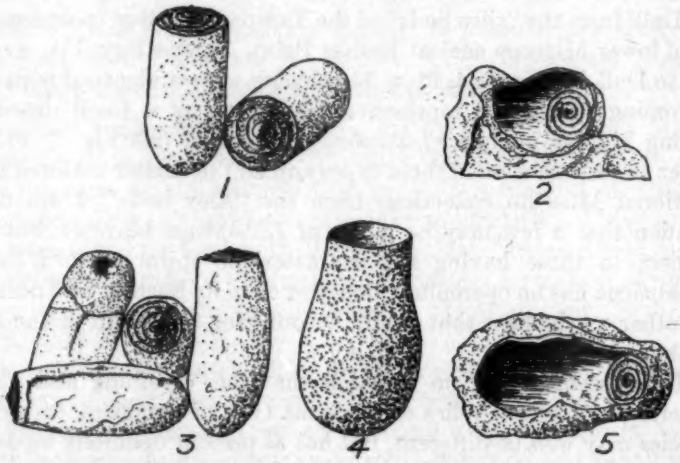


Fig. 1.—Lower Miocene fossil molds from the "silex beds" of the Tampa limestone, Tampa Bay, Fla. Fig. 2.—Apical interior of the larval chamber of *Entechnia taurea* (Say) Patton. Fig. 3.—Upper Eocene fossil molds from Mountainview, Wyo. The left upright specimen retains a portion of the chamber and seal. Fig. 4.—Sandy larval chamber of a living bee from a cliff near Weiser, Idaho. Fig. 5.—Interior of the larval chamber of *Emphor fuscojubatus* Cockerell. The spiral is the reverse of that in Fig. 2. All figures natural size.

east side of an irrigation ditch, I found an exposure of soft sandstone the face of which was riddled with small holes, a centimeter or less in diameter. When excavated, these proved to be the entrances to the burrows leading to the larval chambers of a living species of mining bee, presumably an anthophorid. The chambers were well-formed with thin walls of fine sand held together by a dark brown cement. Some were empty, some were filled with sand and other debris, but a few were sealed and apparently perfect (Fig. 4). They contained, however, only small masses of pollen and remnants of pupa cases, principally of dermestid beetles. Further search did not produce an unmolested, loaded chamber, so that the exact identity of the

builder remains unknown. The opened chambers, though disappointing in contents, nevertheless revealed some startlingly arresting characters. These were the size, shape, and smoothness of the interiors and the faint spiral mark on the inside of the seal. Could such interiors have been the molds from which nature by geological processes cast the problematic objects brought back from Wyoming by the Smithsonian expedition?

On my return to the Capital I sought the advice and assistance of entomologists working at the U. S. National Museum, in particular, R. A. Cushman, J. C. Bridwell, and Grace A. Sandhouse, who searched their collections and produced, among others, the larval chamber of an anthophorid bee, *Emphor fuscojubatus* Cockerell (perhaps a form of *Emphor bombiformis* Cresson), collected at Chesapeake Beach, Md., by Bridwell in 1920. The apical interior of this specimen (Fig. 5) and that of a chamber of *Entechnia taurea* (Say) Patton, collected by Bridwell and the writer in an abandoned clay pit near Arlington, Va., October 27, 1934, show the spiral feature of the seal very clearly. These spirals are counterparts of those on the fossils in that instead of having grooved turns they have turns whose surface is convex toward the interior of the chamber. Examination of the abundant material of *Entechnia taurea* from Arlington indicates that the spirals of the chambers containing well-developed healthy larvae are almost always faint or completely obliterated; but that those in cells which were not provisioned or that proved to be "duds" for one reason or another, are usually sharply defined.

Since the sealing of the chamber is an operation performed in the privacy and semi-darkness of an underground burrow, there is some excuse for the lack of precise recorded observations on the process. A few papers[5] get close to it, but so far I have found only one publication[6] that figures the inside of the seal and speculates upon the technique of its construction. Wesenberg-Lund, however, pictures the inside of the seal (his Fig. 4, Pl. 2) made by *Anthophora parietina* Fabricius as showing concentric circles about a small hole through which, he says, the bee thrust her tongue and coated the surface with

[5] GROSSBECK, J. A. *A contribution toward the life history of Emphor bombiformis Cresson.* N. Y. Entomol. Soc. Jour. 19: 238–244. 1911.
NICHOLS, N. LOUISE. *Some observations on the nesting habits of the mining bee, Emphor fuscojubatus Cockerell.* Psyche 20: 107–112. 1913.
BISCHOFF, H. *Biologie der Hymenopteren.* Biologische Studienbücher 5: 229–230. 1927.
RAU, PHIL. *The nesting habits of Emphor bombiformis Cresson.* Brooklyn Entomol. Soc. Bull. 25: 28–34. *figs. 1–5.* 1930.

[6] WESENBERG-LUND, C. *Traek af Linnes vaegge-bi's (Anthophora parietina Fabr.) biologi og anatomi.* Entomolgiske Medelelser (Copenhagen) 2: 97–120, *pl. 2.* 1889–90.

a limy substance. I have not seen chambers of *A. parietina*, but those of *A. abrupta* Say, a related species, do not suggest confirmation of all Wesenberg-Lund's conclusions. The cells of this species are lined with a thin white coating, but it does not react with either hydrochloric or acetic acid, the latter being the reagent used by Wesenberg-Lund. The minute hole may or may not be present, as is also the case with *Entechnia taurea*, but the marks around it are the turns of a spiral and not of concentric circles. Bischoff, cited above, also records spirals in the genus *Tetralonia*. Lack of further adequate material prevents an authoritative statement at this time as to how widespread is the occurrence of the spiral seal among the mining bees, or whether some species make more conspicuous spirals than others.

The existence of suggestive living forms from the predecessors of which the fossils may possibly have been derived, having been pointed out, it will now be necessary, since direct testimony is absent, to marshal the circumstantial evidence in support of the probability that the fossils may be the molds of the interiors of the larval chambers of a hymenopteron. It is not my intention to tie the fossils to any particular living genus and species, but rather to suggest that the relations between the two phenomena are those of biologic affinity and not merely of striking analogy.

The size and shape of the fossils with their spiral apices conform to the interiors of the larval chambers of some anthophorid bees. In these characters the bee chambers vary considerably. Some are long, of medium width, and more or less slightly bent; others are short, stout, and straight. Some are constricted rather sharply at the apex; others are more wide-mouthed. The spirals of the seal are sometimes perfect, sometimes crude, or perhaps absent altogether. They may be high, low, or even depressed, that is, with the apex directed toward the interior of the chamber. All these features and their variations find counterparts in the fossils. In some instances the fossils have irregular deposits of clay on their surfaces that apparently represent portions of the wall and neck of the larval chambers in which they were formed.

In conjunction with the characters already mentioned, the smoothness of the fossil surfaces may be offered as additional corroborative evidence. These smooth surfaces are the kind one would expect to find on fossils derived from the polished interiors of bee chambers by the infiltration of mineral substances. This smoothness suggests that the fossils originated from bee rather than from wasp chambers, because, according to well-authenticated observations, many digger

wasps that store their larval chambers with animal prey, build rough, unfinished chambers and do not seal them with a cemented plug but merely kick sand and soil into a compact heap at the mouth of the cell and continue thus to fill up the burrow to the exit at the surface of the ground. On the other hand, the colonial mining bees that gather nectar and pollen, polish and veneer their chambers, leaving the surfaces smooth and, for a time, relatively impervious. This procedure is apparently necessary to prevent leakage from the interior and damage from the exterior during the filling of the cell and the development of the larva as it feeds upon the stored liquid or semi-liquid provisions.

It may be objected, as an alternative explanation, that the spiral apex of the fossils means relationship to a snail. This suggestion, however, cannot be entertained because the spiral is the only snail characteristic present in the fossils. The shell of no gastropod mollusk of land, fresh water, or marine type fits either the form or the locality requirements of these fossils.

Can a sequence of circumstances be imagined that would explain the origin of these fossils from bee chambers without doing violence to geologic principles? A satisfactory reply to this question must obviously first account for the absence of actual insect remains in the fossils. Since limestone strata in many parts of the world are noted for their rich fossil contents, why should these calcite molds not preserve the pupal skins or other parts of the former inhabitants of the chambers? The explanation is empirical. The purer fossiliferous limestone strata rarely, if ever, preserve the softer, phosphatic portions of organisms but do preserve such hard parts as shells and bones, or their impressions, from which most or all the phosphates have been leached and been replaced by calcium carbonate. It is therefore not surprising, at least to a paleontologist, to find no insect remains in these almost pure calcite molds.[7]

The geologic method by which these molds originated is that illustrated by the formation of those geodes that are the result of cavity fillings. It was necessary that a fortunate geologic incident cause the bee chambers to be bathed for a time in waters charged with calcium carbonate or bicarbonate, so that those infiltrating solutions could fill the cavities. Since the exact source-bed from which the Wyoming fossils were weathered is not definitely known, it seems almost idle to speculate on the precise nature of the geologic incident or series of

[7] See discussion of chitin in PACKARD, A. S. *A textbook of entomology*, p. 29, 1898.

incidents that caused the influx of lime waters to the area of the bee chambers. Was it faulting, land-slipping, subsidence, climatic change, collapse of a sink, or some other event that brought the chambers within the influence of such waters and permitted the infiltration and precipitation of calcium carbonate? The habitats of living anthophorid bees are varied and it is not inconceivable or unreasonable that in the relatively long course of Tertiary history a few favorable accidents should have resulted in the production of fossils from bee chambers.

The Florida specimens from the "silex beds" present an interesting variation on this theme in that they are composed of chalcedony instead of calcite. It is my opinion that the bee chambers here concerned were originally located in a sea-cliff, stream bank, or elevated mud flat near the coast. Weathering out of the cliff and falling into the water, or with subsidence of the area, they were buried together with marine and fresh-water debris, the whole forming what is now known as the Tampa limestone. It is quite possible that calcite first filled the unbroken chambers, but that later, with elevation of the strata above sea level, it was replaced by silica, an exchange that seems even now in progress among the fossils in the upper layers of the formation.

Since entomologists agree that the history of the solitary bees and wasps extends backward at least to the Eocene, if not to the Cretaceous, there need be no objection on the score of geologic age to the idea that these fossils may represent objects associated with the life cycle of those Hymenoptera. The present geographic distribution of the anthophorid bees is amply sufficient to include occurrences in Wyoming and Florida, and by inference I judge that some species may have been as widely distributed in upper Eocene and lower Miocene time. I have not seen the photographs or specimens reported by Buxton[8] of supposed bee chambers taken from a cave in Palestine. They were, however, associated with remains of ancient man and are, therefore, apparently of late geologic age.

If the identification of these fossils as stated here is correct, the unbroken specimens with seal intact suggest, in effect, tragic incidents of the insect world of 30 million years ago. Then, as now, on account of parasitism and other causes, many bee larvae never matured to break the seals of their earthen chambers and to emerge as adults. The fossil molds are the only records of their frustrated lives.

[8] BUXTON, P. A. *Ancient workings of insects, perhaps bees, from Megiddo, Palestine.* Entomol. Soc. London Proc. 7: pt. 1: 2–4. 1932.

For the purpose of convenient reference I have deemed it wise to name these fossils but without implying identity with any living species of bee. The name, *Celliforma spirifer*, is designed to mean "the spiral-bearing form of a cell."

PALEONTOLOGY.—*Land shells from the Upper Eocene Sespe deposits, California.*[1] G. DALLAS HANNA, California Academy of Sciences. (Communicated by JOHN B. REESIDE, JR.)

Fossil land shells have been found so seldom in the older Tertiary sedimentary rocks of California that the small collection of specimens, submitted to me by Dr. Chester Stock, seems well worthy of record. The shells were found in the course of quarrying operations for fossil vertebrates in the Sespe deposits and are preserved in a dark red and green matrix, so characteristic of the Sespe in general. All of the specimens are more or less imperfect. An association with fossil mammalian remains in the stratum in which they occurred, places their age as upper Eocene.[2] This type may be described as follows:

Helminthoglypta? stocki Hanna, n. sp.
Figures 1 to 3a

Shell large, globose, narrowly umbilicate; whorls about 6½ to 7, sutures moderately impressed; aperture and peristome not preserved, but apparently these are not expanded; shell extremely thin and sculptured only with delicate evenly developed growth lines.

MEASUREMENTS

	Altitude	Diameter
Holotype	32 mm.	38.5 (Slightly immature)
Paratype	27.5	41 (Crushed)
Paratype	26.5	36.5 (Immature)

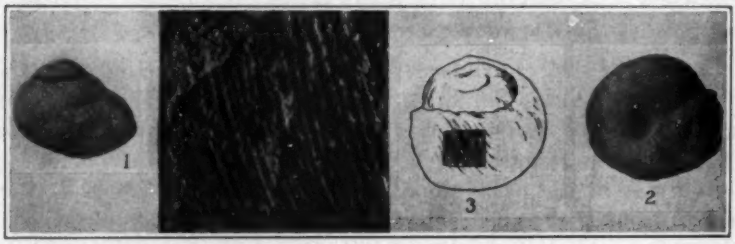
Holotype, No. 3244, and two paratypes, Nos. 3245, 3246, from the upper Eocene Sespe deposits, north of the Simi Valley, Ventura County, California. Field Locality 180 Calif. Inst. Tech. Vert. Pal. Shells in the invertebrate collections of the California Institute.

The essential characters for diagnosis of the species in *Helminthoglypta* are apparent. The moderately elevated spire and generally globose shape are features found in no other west American species. In these characters the Sespe shells resemble *"Helix" leidyi* Hall and Meek[3] from the Oligocene White River Group of the eastern slope of the Rocky Mountains. That species, however, is usually smaller and somewhat more globose, according

[1] Received November 8, 1934.
[2] Stock, C. Proc. Nat. Acad. Sci. 20: 150–154; 349–354. 1934.
[3] HALL, J. and MEEK, F. B. Mem. Amer. Acad. Arts and Sci., n.s. 5: 394, *pl. 5, fig. 12.* 1854. This species was placed in the new genus *Pseudolisinoe* by Wenz (Foss. Cat. pt. 18, no. 2: 365. 1923), the type being *Helix veterna* Meek and Hayden.

to published figures and measurements[4] and specimens in the California Academy of Sciences.

The only living species in California comparable to this in shape is a large form belonging to the *H. tudiculata* group collected in 1933 by C. C. Church in Tulare County. In a set of nine shells collected by Mr. Church, the largest is 42 mm. in diameter and 29 mm. in altitude; the smallest is



Figs. 1–3*a*.—*Helminthoglypta*[5] *stocki* Hanna. Fig. 1.—Holotype, no. 3244, anterior view. Fig. 2–3*a*.—Paratype, no. 3246. Fig. 2.—Basal view. Fig. 3a.—Enlargement of sculpture lines whose position is shown by rectangle in fig. 3.

36 mm. and 26 mm., respectively. Thus the shell is less globose than the Sespe fossil; also the surface of the living form is heavily malleate. Messrs. Church and A. G. Smith have the Tulare County shell under consideration for description.

The Tejon form, *H. obtusa* Anderson and Hanna[5] is much smaller (diam. 16 mm.), less depressed, and altogether a different shell. *Micrarionta dallasi* Hanna,[6] from the Eocene of the San Diego region, is likewise smaller (diam. 10.5 mm.) and less globose. No other described fossil forms appear to be sufficiently close to need comparison. Several small collections of land shells have been obtained by various parties during recent years in the southeast corner of Kern County, in a Tertiary formation which has been called "Walker." Preservation is usually rather poor and critical study has been postponed in expectation that better material might be discovered. It is possible that the present species may be there represented. The age of the formation is somewhat uncertain, but it lies below the Temblor (middle Miocene) and rests upon granite. The best specimen available was collected by William Barbat, 1,000 feet west of Pyramid Hill, Kern County, in sediments that were thought to belong to the lower Temblor. This shell has a dome-shaped spire, closed umbilicus, and is considerably larger than any of the Sespe specimens.

[4] COCKERELL, T. D. A. and HENDERSON, JUNIUS, Bull. Amer. Mus. Nat. Hist. 31: 232, *pl. 22, figs. 1–3*. 1912.

[5] ANDERSON, F. M. and HANNA, G. D. Occ. Papers Calif. Acad. Sci. 11: 142, *pl. 3, figs. 12, 13*. 1925.

[6] HANNA, M. A., Univ. Calif. Publ. Geol. 16: 330, *pl. 57, figs. 8, 11*. 1927.

The problem of allocation of fossil land shells to the proper genera has been difficult for paleontologists to solve. The temptation is strong to create new group names without tangible morphological characters and solely on the basis of geologic or geographic position of the specimens. However, it seems best in this regard, when no pronounced structural differences can be found, to follow the work of such authors as Pilsbry,[7] Cockerell and Henderson and refer the species to the genus which lives in the region today.

[7] PILSBRY, H. A., Manual of Conchology, ser. 2, vol. 9, p. XLIV. 1894.

PALEONTOLOGY.—Pleurotomaria pseudostrigillata *nom. nov. and* Chonetes acanthophorus *nom. nov.*[1] GEORGE H. GIRTY, U. S. Geological Survey.

In the course of describing the Guadalupian fauna in 1908[2] I unwittingly named one of the species *Pleurotomaria strigillata*, overlooking the fact that Herrick[3] had already described a Waverly species under that name. The Guadalupian species should now be known as *Pleurotomaria pseudostrigillata*. Furthermore, Mr. Ralph H. King has considerately called my attention to the circumstance that my *Chonetes granulifer* var. *armatus*[4] is virtually a homonym of *Chonetes armatus*[5] Norwood and Pratten 1854, a name even at that time preoccupied by Bouchard.[6] I propose to substitute *Chonetes acanthophorus* for the form found in the Wewoka formation. Acknowledgment for some of these references is gratefully made to Mr. King.

[1] Published by permission of the Director of the U. S. Geological survey. Received November 8, 1934.
[2] U. S. Geol. Survey Prof. Paper 58: *pl. 24, figs. 21, 21a.* 1908.
[3] Bull. Sc. Lab. Denison Univ. 3: 86, *pl. 1, figs. 10, 15; pl. 2, fig. 25.* 1888.
[4] U. S. Geol. Survey Bull. 544: 62, *pl. 7, figs. 2–4.* 1915.
[5] Acad. Nat. Sci. Philadelphia Jour. 3: 28. 1854.
[6] See MURCHISON, DE VERNEUIL, and KEYSERLING, Geologie de la Russie, etc. 2: 241. 1845.

BOTANY.—*The inflorescence in* Schizostachyum *Nees.*[1] F. A. MCCLURE, Lingnan University. (Communicated by A. S. HITCHCOCK.)

During the course of a study of the Chinese species of *Schizostachyum* just completed,[2] it became apparent to the writer from a comparison of numerous herbarium specimens with their published descriptions, and from a study of various published descriptions of the genus, that the structure of the inflorescence is not as well understood as it should be. Reasons for this are not difficult to find. The fluid and unusual nature of the inflorescence in this genus has caused no

[1] Received July 27, 1934.
[2] To appear shortly in the Lingnan Science Journal.

end of confusion, and the terminology used in the descriptions has, almost without exception, been inconsistent and misleading, largely because of faulty interpretations of the component structures.[3]

Although Nees (1829) made allusion, in the name of the genus,[4] to one of its fundamental characters, it would seem, judging from his description, that he did not himself fully comprehend the significance of the character in terms of the morphology of the inflorescence.

The genus was briefly described by Nees on the basis of a single species collected by Blume in Java. When Ruprecht (1839) prepared his monograph two additional species were recognized. Ruprecht revealed a sense of dissatisfaction with Nees's terminology as well as an uncertainty as to the correctness of his own, and for the most part his description of the genus shows little improvement over Nees's. In fact, among other errors he made the mistake of calling the spikelets 3-flowered. Nevertheless, in a footnote (op. cit., p. 134) he arrives at a statement "Glumae in descr. Neesii sunt nostrae valvulae floram (in icone) *vel rectius bracteae spiculas vel gemmas includentes* . . ." (italics mine), which points the way to a better understanding of the inflorescence. Judging from the terminology of subsequent descriptions, however, no one seems to have given any serious attention to this hint.

Nees's original description of the genus (op. cit., p. 535) together with an emended description prepared by the writer on the basis of a study of the Chinese species, will provide a background for the discussion that follows.

SCHIZOSTACHYUM†

"Spiculae teretiusculae, glomerato-spicatae, inferne compositae interjectis inter glumas pedicellis sterilibus, uniflorae. Glumae inferiores alternatim minores, aequinerviae; superiores tres aut quatuor majores, circumvolutae, aequinerviae, quarum suprema sola fertilis. Valvulae distinctae nullae (nisi supremas squamas glumiformes valvulas existimes). Lodiculae nullae. Stamina sex, antheris linearibus erectis. Stylus simplex, longus; stigmata tria, pubescentia. Caryopsis ignota.

"Inflorescentia: spicae terminales ramorum approximatae, simplices. Spiculae in glomerulos dissitos congestae, spathis scariosis variis suffultae et interstinctae. Gramina vere bambusoidea, arborescentia, foliis petiolatis."

SCHIZOSTACHYUM BLUMII†

"Species una nobis cognita, foliis est fere pedalibus oblongo-lanceolatis acuminatis glabris, vaginis ore nudis, ligula brevissima.

"*Habitat in Java Insula: cl. Blume.*

[3] It is probable that the neglect of the prophylls as constituting a category distinct from the bracts and glumes, and the consequent failure to use them as orienting structures, are largely responsible for this faulty interpretation.

[4] From the Greek: σχιζαγ = *split*, and στάχυσ = *spike*.

"Adnot. Genus Beesha Kunth., Melocana [sic!] Tr. (Bambusa baccifera, Roxb. (Beesha *Rheed. H. Mal. V.* t. 60), nostro quoad spiculas proximum, differt inflorescentia, valvulis (si modo recte observata sint a scriptoribus) diversa forma distinguendis, fructu bacciformi."

The following is the writer's characterization of the genus based on a study of the Chinese species.[5]

SCHIZOSTACHYUM Nees emend.

CLUMP HABIT dense or open; RHIZOME sympodial,[6] with a tendency in some forms to run a little distance laterally before turning upward to form the culm, thus giving rise to a more open clump habit; CULMS erect or ascending, terete, thin-walled, usually straight, sometimes somewhat zigzag, the tips upright, drooping, or clambering; *nodes* not prominent, but usually bearing a narrow ring of pithy tissue left from the base of the deciduous sheaths; *internodes* cylindric, each smooth and shining at its base, the remaining portion with a siliceous covering which increases in thickness toward the summit of the internode, the siliceous part at first variously strewn with brittle, appressed, acicular hairs, ultimately more or less glabrescent, a zone of varying width just below the nodes usually being somewhat glaucous, more densely covered with these hairs, and more tardily glabrescent; *prophylls* (at culm nodes) ovate, obtuse, flat, shining, each containing numerous (up to 10) buds[7]; BRANCHES numerous, subequal, in fascicles, slender, the basal 2 to 6 internodes short, closely clothed with short, more or less persistent, imbricate sheaths, each sheath usually bearing in its axil a prophyll containing dormant or active buds, the branches rarely rebranching at their distal nodes; CULM SHEATHS cylindric, convolute, coriaceous-chartaceous, usually more or less conspicuously striate or ribbed, siliceous, usually more or less covered with brittle, acicular hairs and ultimately glabrescent; *auricles* usually obsolete or nearly so; *oral setae* usually prominent; *pseudophylls* reflexed, long and narrow with involute margins and subulate tips; BLADES of widely varying size and shape, even on the same plant, acuminate, subulate or acicular, usually more or less rough to the touch on one or both surfaces, sometimes entirely glabrous on one surface or the other, always with several scabrous veins along the outer margin of the upper surface; the *margins* cartilaginous and more or less scabrous; the secondary veins on the under surface often with a tessellate appearance, especially in young leaves; INFLORESCENCES arising from solitary buds[7] but forming clusters, often in heads when older, sometimes more lax and open, terminal or lateral on leafy or leafless branches of primary, secondary or even higher order, sometimes (in *S. dumetorum* Munro at least) borne directly on the nodes of the main culm; the *main axis* (of the inflorescence) and the *rachis branches* of all subsequent orders, short, deter-

[5] Hitherto only 2 species have been recorded from China: *S. chinense* (a rather aberrant species, concerning the vegetative characters and habit of which little is known) and *S. dumetorum*. To these have been added *S. lima*, formerly known only from the Philippine Islands, and two newly described, apparently endemic species.

[6] Sympodial rhizomes are short and thick, with congested nodes, and are early determinate, i.e., after growing horizontally for a short distance they turn upward to form a culm. This type of rhizome gives rise to a more or less crowded or caespitose type of clump. For a fuller definition of the meaning of this term as used by the writer, see Lingnan Agr. Rev. 3: 40–47. 1925.

[7] The examinations were made by ordinary dissection. This point should be checked by means of serial sections of the branching structure during its young stages.

minate, ultimately much branched, the branching system being indeterminate, becoming predominantly sympodial with age, the individual rachis branches each with a prophyll at its base and completely covered, in its early stages, with crowded imbricate bracts, the terminal rachis joints elongate, with expanded apices, each bearing a 1-flowered spikelet; *prophylls* (of the inflorescence) 1–8 mm. long, triangular and obtuse to linear-lanceolate and acute, the keels white-ciliate; *bracts* 1-several, gemmiferous, ovate to sublinear, obtuse and awnless to acute and more or less definitely awned, few- to many-nerved, sometimes with the central nerve forming a keel, glabrous or variously pubescent, the upper ones approaching the lemmas in size and shape; *spikelets* 1-flowered, sessile, perfect, staminate or intermediate (rudimentary perfect), the perfect ones promptly deciduous, the intermediate ones more tardily so, and the staminate ones persistent; *glumes* entirely lacking (except in *S. chinense* Rendle); *sterile lemmas* wanting (except in *S. chinense*); *lemmas* convolute, resembling upper bracts of the pseudo-spikelets, thin-chartaceous to more or less indurate, many-nerved, obscurely to definitely awned, shorter than the palea in perfect spikelets, longer than the palea and completely enveloping it in the staminate and rudimentary perfect spikelets; *paleas* convolute, often more or less spirally twisted, soft and flexible at the base, firm above, not obviously keeled but bearing dorsally a slender rachilla-joint lying in a shallow, inconspicuous sulcus, the latter becoming wider and deeper near the notched, or more or less prominently bifid, indurate apex; *rachilla* not disarticulating (except the basal joint in *S. chinense*), the terminal joint (at back of palea) pearly-white, flattened at the base, slender, bristle-like, often tipped with a minute, bud-like or leaf-like structure (rudimentary floret?), the latter being more conspicuous in staminate spikelets; *lodicules* wanting (except in *S. chinense*); *stamens* 6 (sometimes 7), included or exserted, with flat filaments, the anthers with blunt apices and unequally bifid bases; *pistils* stipitate, with the narrow, linear ovary attenuate into a slender style terminated by usually 3, sometimes 2, plumose stigmas; *fruit* (in *S. dumetorum*; unknown for the other Chinese species) fusiform, with a long, slender beak, the coriaceous pericarp separable from the grain or seed except at the back.

The inflorescences of the Schizostachyums that have been studied by the writer are borne at the distal nodes of leafy or leafless branches of primary, secondary or even higher order, or they may sometimes be borne directly upon the nodes of the main culm. The primary buds giving rise to the inflorescences are apparently solitary, but each develops into a complicated, though usually short, branching system. The main axis and the individual branches of the rachis are more or less promptly determinate, always ending in a 1-flowered spikelet, which may be perfect, staminate, or intermediate. Moreover, there is a tendency, more obvious in older inflorescences, toward typical sympodial branching (fig. 1, A and B).

While the individual branches of the rachis are thus determinate in their development, the inflorescence as a whole is entirely indeterminate, being enlarged, or rather made more dense, by the continued development of new branches from the buds in the axils of the bracts. The writer has records which indicate definitely that in several species of this genus a given in-

florescence may produce new rachis branches and new spikelets in the second year. This behavior is apparently common to all the species studied, and it is probable that the process may go on for an even longer period than has been indicated by the records. Camus (1913) p. 173, no doubt refers to this same phenomenon when he says of *S. Zollingeri* Steud. "parfois les fascicules inférieurs prolifères."

Pilger (1927) observed the presence of a similar branching system in the

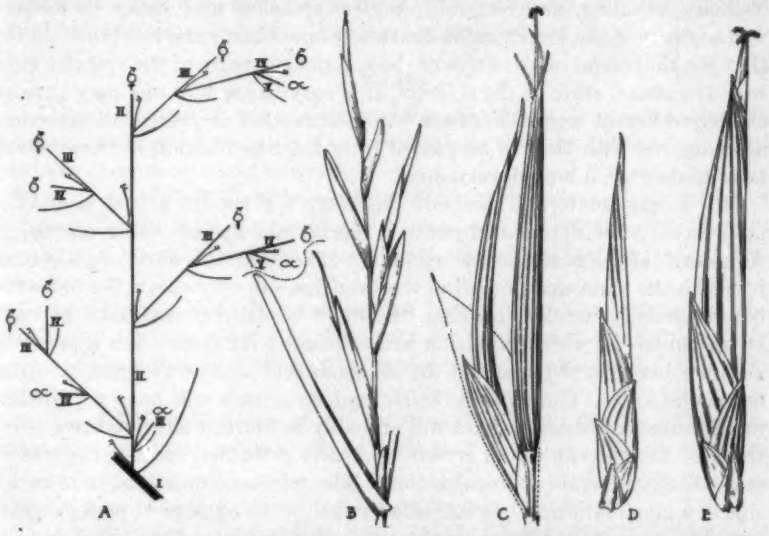


Fig. 1.—A. Diagram of an inflorescence of *Schizostachyum lima* which may be taken as typical for the genus. The Roman numerals indicate the order of the rachis branches, counting the branch from which they originated as I. ♀ indicates fully developed perfect spikelets; ♀ indicates rudimentary perfect spikelets; ♂ indicates staminate spikelets; ∝ indicates a bud or an incompletely developed branch. The bracts, and the sheath subtending the inflorescence, are indicated by simple curved lines, while the prophylls are shown as curved lines with two short lines inserted at right angles at their tips. B. A sketch of an inflorescence of *S. lima*. Some of the bracts, as well as the sheath subtending the inflorescence, have lost their pseudophylls. ×1. C. A portion of the tip of a rachis branch (pseudo-spikelet) of *S. lima* in an advanced stage of development. The lateral buds have produced branches which destroy its original spikelet-like appearance. The perfect spikelet (terminal) is supported by a short lateral branch (another little pseudo-spikelet) terminated by a staminate spikelet. The subtending bract is indicated by broken lines. ×3. D. A small pseudo-spikelet of *S. hainanense* terminated by a staminate spikelet. ×5. E. A pseudo-spikelet of *S. hainanense* terminated by a perfect spikelet. Note the 2-keeled prophyll at its base. Each of the four bracts bears in its axil a bud capable of developing into another pseudo-spikelet. ×5.

inflorescence of *Guadua tessmannii* Pilg., and Möbius (1898) recorded for *Bambusa vulgaris* Wendl. the development, in the second year of its flowering, of buds from a year-old rachis branch into new "spikelets." It is probable that this behavior is more common in other genera also than is generally suspected.

It is important to point out, at this juncture, that the fully developed perfect spikelets are rather promptly deciduous, while the rudimentary perfect ones fall much more tardily, the staminate ones being persistent. This behavior, operating along with the continuous development of new rachis branches, results in a growing preponderance, in specimens which have been flowering for some time, of imperfectly developed (or rudimentary) perfect spikelets, along with the staminate ones. In the course of ordinary handling, any remaining perfect spikelets may easily be lost, as well as many of the somewhat rudimentary ones. And when it is remembered that the shape and relative size of the component parts of the spikelet vary with the sexual state of the spikelet, it is easy to see how one may gain an entirely different impression from the examination of young inflorescences as compared with that to be gained from the examination of those which have undergone a long development.

It is an easy matter to ascertain the relative, if not the actual, age of the inflorescences of Schizostachyums in herbarium specimens or elsewhere. As a result of the continued development of additional branches in a system in which the main axis and all of the branches are very short, the older the inflorescence, generally speaking, the more crowded it will have become. In specimens in which flowering has continued for more than a year the contrast between the new and the old parts will be readily apparent when one looks for it. The older spikelets and structures will have a blanched appearance and be brittle, and will probably be more or less damaged, while those of the current year's growth will have a fresher, firmer appearance, and will often retain a greenish tinge. The relative number of bare rachis tips in a given inflorescence will be an index to the number of perfect spikelets that have fallen. Furthermore, it should be remembered that in fully developed perfect spikelets the palea always is exserted, however slightly, beyond the tip of the lemma. If there are no spikelets in this condition, the inflorescences are either very young (in which case there will be no naked rachis tips) or they are very old (in which case the naked rachis tips will be relatively numerous.

The branches of the rachis are covered with gemmiferous bracts.[8] Before their buds have developed, these branches have the appearance of spikelets, for which structures they have commonly been mistaken (fig. 1, D and E). The presence, however, of a prophyll[9] (often described as a 2-keeled glume) at the base of each, and of buds in the axils of the bracts (so-called gem-

[8] In the very rare cases where a bud was not found in the axil of a bract, it seemed likely that, being quite small, it was overlooked or lost.

[9] The prophyll has been largely neglected in the published descriptions of bamboos. And while it is not entirely lacking in taxonomic value, Takenouchi (1931) has perhaps over-emphasized the usefulness of its characters for distinguishing species. This structure has been of the greatest value to the writer, however, as an orienting structure leading to an understanding of the morphology of the inflorescence in *Schizostachyum*, where the small size and the extremely crowded condition of the floral structures make ordinary dissection particularly difficult. It is perhaps in connection with this aspect of bamboo study that its usefulness should be more strongly emphasized.

miferous glumes), reveals their true nature immediately.[10] As soon, however, as the lateral buds of a given rachis branch have developed to any extent, it loses its spikelet-like appearance, and the terminal spikelet itself becomes more evident. In those species which have the terminal rachis joints most elongate, the true spikelet is likewise more easily discernible. In such species the terminal perfect spikelets are typically seen to be supported on one side by a short rachis branch terminated by a staminate spikelet (fig. 1, C). Camus (1913), p. 177, would seem to be referring to this condition when he says of *S. latifolium* Gamble, "Epillets . . . groupés par 2 . . ."

SUMMARY

1. The structure of the inflorescence in the genus *Schizostachyum* has been misinterpreted since its first description, and the terminology used has been inconsistent and misleading.

2. It is suggested that the neglect of the prophylls as constituting a category distinct from the bracts and glumes, and the consequent failure to use them as orienting structures are largely responsible for this faulty interpretation.

3. As a background for the discussion Nees's original description of the genus and the type species is given, along with the writer's own recently prepared emended description of the genus based on a study of the Chinese species.

4. The following sources of confusion in the interpretation of the inflorescence of *Schizostachyum* are pointed out:

a. The indeterminate nature of the inflorescence as a whole, which grows out of the successive development of additional rachis buds.

b. The unusual, spikelet-like form taken by the determinate rachis branches (pseudo-spikelets).

c. The fact that the spikelets terminating these branches of the rachis may represent any sexual state from purely staminate, through rudimentary perfect, to fully developed perfect, with corresponding discrepancies in the shape and relative size of the different component structures.

d. The fact that there may exist, in a given inflorescence at a given moment, spikelets (as well as the rachis branches which they terminate) in various stages of development.

e. The prompt deciduousness of the fully developed perfect spikelets, which leaves, in the older inflorescences, an impression that certain more tardily deciduous forms of the spikelet are representative, because most numerous.

[10] As an aid in making clear the distinction between these structures and the real spikelets, the term *pseudo-spikelet* has been used, in the descriptions recently prepared by the writer, to indicate these bract-covered ultimate branches of the rachis. The proper significance of this term, as well as the modern sense of the terms *bract* and *glume*, (Chase, 1922 and Piper, 1906) should be kept in mind in comparing these with the older descriptions. The structures referred to in the existing descriptions as "glumes" or "gemmiferous glumes" are really, for the most part, *bracts*. Glumes, in the modern sense, are lacking in all the Chinese species of the genus except *S. chinense*. This species is also aberrant among the Chinese species in the possession of lodicules, a sterile lemma, and a disarticulating rachilla.

ACKNOWLEDGMENTS

The present paper is the beginning of the fruition of field work on the Chinese bamboos begun in 1921, and is based on herbarium material and notes brought together chiefly by the writer and the staff of the Lingnan University Herbarium. Full acknowledgment is made elsewhere of special financial assistance for this work received from various outside sources, but special mention is due the Rockefeller Foundation for its most recent grant, which has made possible the purchase of hitherto unavailable literature and equipment essential to the continued pursuit of this work.

The writer wishes to acknowledge his great indebtedness to Dr. A. S. Hitchcock and Mrs. Agnes Chase for assistance and advice, and for numerous courtesies in connection with the use of their unexcelled private agrostological library, and the grass collections of the United States National Herbarium.

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[11] This paper was first issued in 1839 as a separate with pagination 1–74. When it appeared in the regular series in 1840 the pagination was changed to 91–164. Thus, in the latter place our reference would be pp. 133–7.

BOTANY.—Pleuroderris, *a new genus of Middle American ferns.*[1] WILLIAM R. MAXON, National Museum.

The genus *Hypoderris* R. Br., first mentioned with a few words of description in 1830,[2] was fully described and figured somewhat later by Hooker[3] on the basis of a single species, *H. Brownii* J. Sm., from Trinidad, which has since been found rather commonly in Porto Rico, also in Hispaniola and Grenada, and very recently has been reported from Venezuela.[4] This plant has the general habit and venation of *Tectaria trifoliata*, and in fact closely resembles young individuals of that species. It has been classified nevertheless as belonging not to the Dryopterideae, but to the tribe Woodsieae, because of its curious indusia. These are inferior in attachment and at first subglobose, enclosing the sporangia, but soon become circular, pateriform and flattish, and shallowly lobed on all sides, with fimbriate-ciliate margins.

In addition, five other species have been described under *Hypoderris*, for the most part independently or upon scant material. The latest of these, *H. Stuebelii* Hieron.,[5] founded upon a sterile plant from Ecuador, has since been referred to *Leptochilus*.[6] Of the remaining four, two were described from Nicaragua by Fournier, one from Nicaragua by Prentice, and one from Guatemala by Christ. All five, though exhibiting great variation in leaf form according to age and habitat, as well as in soriation, actually represent but a single species, which departs widely in sorus characters from the genotype, *H. Brownii*, and may be regarded tentatively as constituting a new genus. However, this plant had previously been described from the Darien region as *Lindsaea* (*Dictyoxiphium*) *Michleriana* Eaton, which is thus the name-bringing synonym. Because of the laterally attached indusia its repeated description by several authors under *Hypoderris*, in which, as already remarked, the indusium is truly inferior in attachment, is hard to understand, whatever its true relationship may be. Oddly enough the presence of any indusium whatever was overlooked by Baker in describing in the Synopsis Filicum this species once more as new, from Nicaragua, under the name *Polypodium* (*Dictyopteris*) *Tatei*. In the same volume also (p. 113) Baker re-

[1] Published by permission of the Secretary of the Smithsonian Institution. Received October 30, 1934.
[2] R. Br. (note) in Wall. Icon. Pl. Asiat. Rar. 1: 16. 1830.
[3] Gen. Fil. *pl. 1.* 1838.
[4] Revista Sudamer. Bot. 1: 82. 1934.
[5] Hedwigia 46: 323. 1907.
[6] *Leptochilus Stuebelii* (Hieron.) Maxon, Proc. Biol. Soc. Washington 46: 142. 1933.

described *Lindsaea Michleriana* under the genus *Lindsaea*, transferring it however to the subgenus *Diellia*, obviously on the basis of specimens at hand. So we have the rare anomaly of his recognizing one and the same species under three wholly different names, contemporaneously, viz., *Lindsaea Michleriana*, *Hypoderris Seemanni*, and *Polypodium Tatei!*

Type material of all six of the "species" just mentioned has been studied by the writer in connection with a very ample recent series of specimens from the lowland region of Juan Diaz, about 10 miles east of Panama City. From this whole range of specimens the new genus, consisting of a single highly variable species, is described herewith. Its possible origin as a bigeneric hybrid is discussed below. The name adopted relates to the lateral attachment and position of the indusia.

Pleuroderris Maxon, gen. nov.

Rhizoma suberectum, paleis castaneis praeditum. Folia multa, stipitibus sulcato-angulatis rufo-castaneis inarticulatis; laminae variabiles anguste deltoideo-oblongae, attenuatae, saepe asymmetricae, basi pinnatisectae vel pinnatae, alibi grosse lobatae; segmenta majora pauca deltoideo-oblonga vel lanceolata, infima semiadnata vel sessilia plerumque repando-crenata vel sinuata, media semiadnata vel adnata, repanda vel sinuata vel subintegra, superiora gradatim minora late conjuncta, laminae apice lato elongato sinuato. Costae subtus elevatae; nervi catadromi distantes obliqui subflexuosi; venatio *Tectariae*, areolis inaequalibus saepe appendiculatis. Sori submarginales vel inter nervos irregulariter et sparse dispositi, dorsales vel compitales, magni, lunati vel vermiformes vel varie curvati, receptaculis plerumque elongatis; indusia lateralia, integra vel interdum ut videtur divisa, obscure ciliolata; sporangia numerosissima longe pedicellata plerumque abortiva vel deformia, annulo incrassato ca. 13-articulato, sporis perpaucis alte et tenuiter echinato-alatis; paraphyses nullae.

A terrestrial fern of wet forest ravines, the rhizome stout, suberect, paleaceous. Fronds many, of medium size, ascending, the stipes firm, sulcate-angulate, rufo-castaneous, not jointed to the rhizome; blades variable, narrowly deltoid-oblong, attenuate, often asymmetrical, coarsely lobed, pinnatifid, or (at base) pinnatisect or fully pinnate; pinnae and larger lobes usually few, simple, deltoid-oblong to lance-attenuate, the basal ones of large blades semiadnate or rarely sessile, mostly sinuate to coarsely repand-crenate, those above adnate to semiadnate, long-decurrent, repand to subentire, the upper ones gradually reduced, broadly joined below the broad, greatly elongate, sinuate apex. Costae strongly elevated beneath; veins catadromous, distant, oblique, elevated, subflexuous, nearly reaching the margin; intermediate veinlets freely anastomosing, the costal areoles elongate, nearly or quite connecting the veins at base, the others broadly polygonal, variable, often subdivided, the ultimate areoles with or without simple or forked included veinlets. Sori irregularly disposed in a submarginal zone or sometimes borne in 1 or 2 incomplete sparse rows between the veins, dorsal or compital, mostly large, lunate to irregularly linear or variously curved, the receptacle dark, usually elongate; indusia lateral, entire or (if

greatly elongate) sometimes appearing deeply few-lobed, dark, lustrous, early thrust back and nearly concealed by the sporangia, obscurely ciliolate; sporangia very numerous, long-stalked, mostly abortive or somewhat deformed, the annulus about 13-celled; spores very few, delicately echinate-alate; paraphyses wanting.

TYPE SPECIES: *Lindsaea Michleriana* Eaton, from Colombia, the synonymy being as follows:

Pleuroderris Michleriana (Eaton) Maxon

Lindseya (*Dictyoxiphium*) *Michleriana* Eaton, Mem. Amer. Acad. n. s. 8: 213. 1860.
Dictyoxiphium Michlerianum Moore, Ind. Fil. 319. 1861.
Hypoderris Seemanni Prentice, Journ. Bot. Brit. & For. 7: 240. 1869.
Hypoderris marginalis Fourn. Bull. Soc. Bot. France 9: 260. 1872.
Hypoderris adnata Fourn. Bull. Soc. Bot. France 9: 260. 1872.
Polypodium (*Dictyopteris*) *Tatei* Baker in Hook. & Baker, Syn. Fil. ed. 2, 506. 1874.
Hypoderris heteroneuroides Christ, Bull. Herb. Boiss. II. 6: 292. 1906.

TYPE LOCALITY: "Ad terram prope cataractum Truando Novae Granadae, *Schott* n. 8."

DISTRIBUTION: Northwestern Colombia to Guatemala, at low elevations.

ILLUSTRATION: Shimek in Bull. Lab. Nat. Hist. Univ. Iowa 4: *pl. 18, f. 1–3.* 1897; Hook. Icon. Pl. 17: *pl. 1670.* 1886.

Of the following specimens examined all are in the U. S. National Herbarium (N), unless otherwise indicated:

COLOMBIA: Truando Falls, Intendencia de Chocó, Feb. 1858, *Schott* 8 (herb. D. C. Eaton; dupl. at N. Y. Bot. Gard.).

PANAMA: Muddy border of small stream near Tapia River, one-half mile south of Pacora road, alt. 30 meters, Nov. 29, 1917, *Killip* 2706. Deep woods along Pacora River, Dec. 23, 1917, *Killip* 2734. Deep woods along Tapia River, Dec. 23, 1917, *Killip* 2746. Deep ravine north of Orange River, along muddy banks of small stream, Jan. 13, 1918, *Killip* 2787. Ravines of upper Juan Diaz River region, Mar. 10, 1918, *Killip* 2855. Forest along Juan Diaz River, about 4 miles above Juan Diaz, Jan. 13, 1918, *Mrs. L. R. Cornman* 648. Wet forest along Tapia River, common, Dec. 1923–Jan. 1924, *Standley* 26171, 28211. Edge of waterholes and along stream banks, in stiff clay soil often subject to inundation, near Tapia River, June 1–3, 1923, *Maxon & Harvey* 6666, 6692, 6724.

COSTA RICA: Llanuras de San Carlos, alt. 200 meters, in shade, Apr.–May, 1910, *A. & C. Brade* 487 (Berlin, N. Y. Bot. Garden; photo. and fragm., N).

NICARAGUA: Chontales, *Seemann* 206 (Br. Mus.; type of *Hypoderris Seemanni;* photo. and fragm., N). Chontales, in forest, *Lévy* 501 (type of *H. adnata,* at Paris, not seen; photo. and fragm., N). Chontales, *Lévy* 501 bis (type of *H. marginalis,* at Paris, not seen; photo. and fragm., N). Chontales, *Tate* 41/235 (type of *Polypodium Tatei,* at Kew, not seen; dupl. type at Br. Mus.; photo. and fragm. of latter, N). Near Castillo, "found sparingly on the banks of a creek in deep woods," Jan.–Feb., 1893, *Shimek* s. n. Region of Braggman's Bluff, 1928, *Engelsing* 269.

GUATEMALA: Cubilquitz, Alta Verapaz, alt. 350 meters, *von Tuerckheim* (J. D. Smith, no. 8821; type of *H. heteroneuroides;* 3 sheets, N).

Despite this wide array of material, *Pleuroderris Michleriana* is rare in

Fig. 1.—*Pleuroderris Michleriana* (Eaton) Maxon. The type specimen; about two-fifths natural size.

most herbaria, a single exception being the extensive series in the National Herbarium from the Juan Diaz region, Panama. Many of the Panama numbers are represented by two or more sheets, which show not only "abnormal" variations in leaf form but numerous intermediate stages between the young and adult conditions as well. Eaton's type specimen (fig. 1) consists of two fronds that are somewhat immature in leaf form. The well-developed, mature but not extreme form is shown in an incomplete frond of *Killip* 2787 (fig. 2). Mrs. Cornman's no. 648, from Panama, happens to be an exact match for the type material of *H. Seemanni* and *Polypodium Tatei*, from Nicaragua.

As to relationship, *Pleuroderris* is most like some species of *Tectaria*, but with sori distinctly anomalous in their widely varying structure. The venation is obviously that of *Tectaria*, and the general aspect of the plant hardly less so. The sori arise mostly at the angular intersection of the veinlets which enclose the areoles, as in certain species of *Tectaria*, but they are unique in that the sporangia usually extend in a continuous dorsal line some distance along two or more of the boundary veinlets of an areole and commonly those of an adjacent areole. The sori are thus, as a rule, elongate. Sometimes they are merely lunate or irregularly curved-linear; again they may be T-shaped or Y-shaped, according to the vein-pattern; occasionally they are hippocrepiform or nearly circular in outline. In the last case it will usually be found, on dissection, that the heavy sporangial line runs nearly around the areole and that the laterally attached indusium follows it throughout, being linear in extent though not "linear" in form. Sometimes, also, two or three sori, although of independent origin, arise closely from the same or adjacent areoles and run together at maturity to form a composite "sorus," in which case the indusium may appear coarsely few-lobed. Rarely (e.g., *Maxon & Harvey* 6692) the sorus is essentially that of *Tectaria*, with roundish-reniform indusium, the sporangia arising from a short receptacle. Besides the types just described, occasionally a sorus is borne also at the expanded tip of an included veinlet.

Details of venation and soriation are shown rather imperfectly in the illustrations by Shimek, but this author, in his interesting paper on the ferns of Nicaragua,[7] is apparently the only one to have questioned the reference of the present plant to *Hypoderris*. Although his material was inadequate he contrasted it with the type species, *H. Brownii*, directing special attention to the "transverse" indusium, which is vastly different from the inferior cuplike structure in *H. Brownii*, and concluded that the Nicaraguan plant probably represented a new genus, which however he mistakenly thought should be placed near *Cystopteris*.

The curious position and orientation of the sori in *Pleuroderris* call for comment also. Eaton describes the sori as intramarginal, interrupted, and oblong or linear, and the indusia as slender, interrupted, and "non marginem

[7] Bull. Lab. Nat. Hist. Iowa 4: 115–224. *pl. 1–20.* 1897.

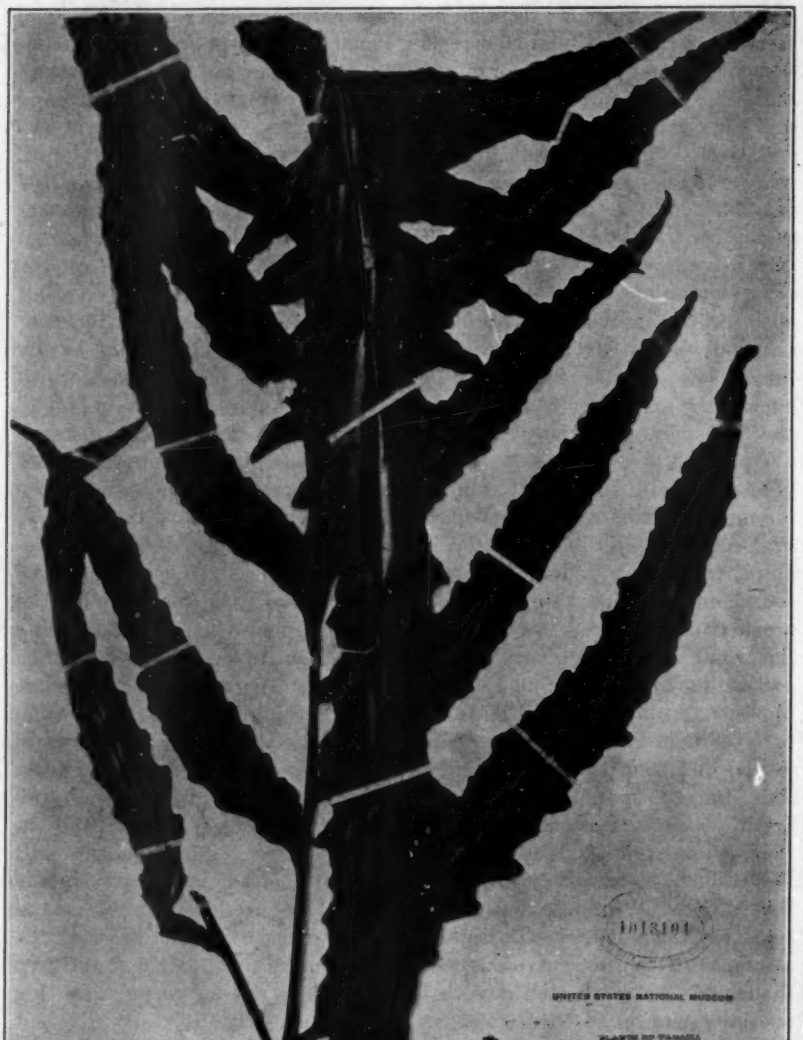

Fig. 2.—*Pleuroderris Michleriana* (Eaton) Maxon. A well-developed Panama specimen, *Killip* 2787; about two-fifths natural size.

frondis tegens." Partly because of the submarginal position of the sori in his sparingly fertile specimens he placed the species in *Lindsaea*, subgenus *Dictyoxiphium*, owing to a supposed resemblance of the sori to those of *Dictyoxiphium panamense* Hook., a newly described genotype which Mettenius,[8] knowing the plant only from description and figure, had reduced to *Lindsaea*. However, *Dictyoxiphium* has long since come to be recognized as a valid "monotypic" genus, differing widely in essential morphology from *Lindsaea*. It is a plant having large, simple, sword-shaped fronds similar in venation to *Tectaria*. In spite of similarity in habit and reticulate venation, *Dictyoxiphium panamense* differs markedly from *Pleuroderris* in soriation; the sporangia are borne in an unbroken submarginal line for nearly the entire length of the frond, the sorus being provided with a continuous, delicate, *extrorse* indusium. No such general condition exists in *Pleuroderris*. Here, it is true, the sori are largely borne in a marginal zone, but of those that are actually submarginal a bare majority face outward, some inward, and others in all directions; also they are of all shapes and sizes, and they never form even a subcontinuous series. Moreover, in some fronds the sori are borne far from the margins in a sparse double row between the nerves nearly down to the midrib, as in *Tectaria;* as a rule also the farther they are from the margin the more closely they resemble the sori of that genus. Before the sorus characters were accurately made out, in fact, several early specimens of Mr. Killip's excellent Panama series were referred to *Tectaria*. Further evidence of relationship is afforded by **Tectaria rivalis,**[9] of the Colombia-Panama region, in which the sori are occasionally oblong and provided with a reduced somewhat chitinous indusium strongly suggestive of the kind predominating in *Pleuroderris*.

But if affinity with *Tectaria* may be regarded as established, it appears no less that *Pleuroderris* departs from that genus definitely in the direction of *Dictyoxiphium*, especially in its elongate and occasionally fused sori which tend to occupy a submarginal position. May it not be a hybrid between *Dictyoxiphium panamense* and *Tectaria martinicensis*, even though these belong respectively to the tribes Davallieae and Dryopterideae? Both species were collected in the Juan Diaz region, in very close association with *Pleuroderris*, and both are companion plants of that throughout its range. Additional support for hybridity is found in the highly variable and pronounced asymmetrical shape of many of the blades in *Pleuroderris* and in the sporangia, most of which are somewhat distorted or only partially developed and apparently lack a normal sporogenous content. Coupled with the extreme diversity in shape, position, and size of sori, the last feature is of special importance. Because of the numerous young plants observed in the Juan Diaz region it may be assumed that *Pleuroderris* is there fertile, sparingly so at least, notwithstanding that after repeated examinations only

[8] Fil. Hort. Lips. 105. 1856.
[9] *Aspidium rivale* Mett.; Kuhn, Linnaea 36: 120. 1869.

a few mature spores have been found. Though not wholly convincing, the points mentioned, particularly the intermediate character of variable soriation, offer a good deal of ground in support of hybridity.

However, *Tectaria* itself, in the modern sense, embraces plants with widely different sori and is seriously in need of revision as to American material. And in this connection the phylogenetic relationship of several genera should be considered. In particular, *Hypoderris Brownii*, though placed by most authors in the tribe Woodsieae on account of its basal indusia, was regarded by John Smith as allied to the group we now call *Tectaria*. Thus Bower's conclusions,[10] upon morphological grounds, as to the modified characters of *Hypoderris* and certain other genera of the Woodsieae in the direction of the tribe Dryopterideae are of unusual interest.

Similarly *Amphiblestra*, consisting of a single rare Venezuelan species, *A. latifolia* (Humb. & Bonpl.) Presl, although classified by nearly all fern writers as belonging to the tribe Pterideae, was associated by John Smith[11] "with *Dryomenes*, *Dictyopteris*, and *Aspidium*, especially such as *A. macrophyllum*," i.e., *Tectaria*. Kunze[12] figured and redescribed it under *Pteris*, dryly remarking that although in venation it treads upon *Phymatodes*, *Bathmium*, *Dictyoxiphium*, and other genera he was well satisfied to place it in *Pteris*. The habit, simply pinnate blades, and areolate venation are those of a *Tectaria* with very freely appendiculate areoles, but the marginal sori normally are fused to form a continuous longitudinal coenosorus which lacks a true indusium, the slightly recurved but unmodified margin scarcely functioning as such. Nevertheless, Fournier,[13] working with imperfect Nicaraguan material, redescribed the unique *Dictyoxiphium panamense* as a new species of *Amphiblestra*, so strong is the similarity in venation. Bower discusses *Amphiblestra* in connection with progressive anastomosis in *Pteris*, but leaves its systematic position in abeyance. It may indeed be a *Pteris* ally, but equally it may belong near *Tectaria*, in the Dryopterideae. It should be borne in mind that if the existence of similar indusial structures is not necessarily an indication of close relationship among the ferns, such indusia having very probably developed independently and often relatively late in various phyletic lines, so also their absence or even the development of somewhat diverse types of indusia may not always be regarded as weighing heavily against the common evolutionary origin of plants otherwise similar in structure and in habit. *Amphiblestra* is no more puzzling than *Dictyoxiphium*. These and several other groups which in venation and habit resemble *Tectaria* deserve close morphological study. *Pleuroderris* may not be a bigeneric hybrid, as suspected, yet the remarkable intermediates between *Tectaria* and *Hemigramma* which Copeland[14] discusses and illustrates

[10] The Ferns 3: 99–119. 1928.
[11] Hist. Ferns 194. 1875.
[12] Farrnkr. 2: 43–46. *pl. 118*. 1849.
[13] Bot. Zeit. 31: 8. 1873, as *Amphiblestra simplex*, sp. nov.
[14] Philippine Journ. Sci. Bot. 3: 31. *pl. 1–4*. 1908.

come to mind as a somewhat similar case. In any event it seems decidedly worth while to place on record such facts as are known about the curious plant here called *Pleuroderris* and to give it temporary status as a genus intermediate between *Tectaria* and *Dictyoxiphium*.

ZOOLOGY.—*The histology of nemic esophagi.* III. *The esophagus of* Oesophagostomum dentatum (*Rudolphi*).[1] B. G. CHITWOOD, Bureau of Animal Industry and M. B. CHITWOOD.

This paper is the third of a series dealing with the structure of nemic esophagi. In this paper the same nomenclature is used as in the previous ones (Chitwood and Chitwood, 1934 and 1934). Some notes on the esophagus of *Oesophagostomum dentatum* have been given previously by one of the writers (B. G. Chitwood, 1931), but the detailed structure of this organ was not given.

GROSS MORPHOLOGY

The gross morphology of the esophagus of the adult of *Oesophagostomum dentatum* has been given previously by Goodey (1924). The esophagus of this form is in general clavate, terminating posteriorly in an elongate swelling. Regions such as corpus and isthmus are not grossly discernible, but the regions homologous to the corpus and isthmus may be determined on the basis of nuclear distribution. In the specimens studied by the present writers the esophagus was from 360 to 400μ long, 150 to 190μ of this length comprising the corpus, 50 to 90μ the isthmus, 80 to 90μ the anterior part of the bulbar region, and 40 to 60μ the posterior part of the bulbar region. The internal covering of the esophagus is very definitely modified in the various regions. Throughout the length of the esophagus the walls of the lumen forming the radii converge distally forming an acute angle instead of a cylindrical tube as in oxyurids and rhabditids. At the extreme anterior end the lumen is subtriangular and the walls simple; 10 to 15μ posterior to this the lumen becomes much more clearly triradiate, and near the tips of the radii 6 series of thickenings are present, these being attachment points of the radial muscles. These attachment points are continued posteriad to the beginning of the posterior part of the bulbar region. In the anterior region of the corpus, minute spines project internally from the wall of the esophagus. The dorsal esophageal gland opens at the anterior end of the corpus, but the position of the orifices of the subventral glands has not been determined with certainty by the writers. Goodey (1924) stated that their orifices were situated just anterior to the beginning of the bulbar region.

The esophagus of this species, like the esophagi of other members of the Strongyloidea, undergoes many changes during development. In the first-stage larva it consists of a corpus, isthmus, and valvulate bulb identical in

[1] Received October 18, 1934.

appearance with that of adult rhabditids, while later in the development the valves degenerate and the esophagus becomes much more elongated so that at the third stage, though the regions are still apparent, the general form differs entirely from that of the first larval stage (See Goodey, 1924).

NUCLEAR DISTRIBUTION

The corpus contains 47 nuclei which fall into two general groups corresponding to the precorpus and postcorpus of other forms. However, there appears to have been some shifting of the relative positions of a few nuclei, making it difficult to set a sharp line of demarcation between the two groups. For practical purposes the first group of marginal nuclei are arbitrarily considered as indicating the beginning of the postcorpus.

Precorpus. The precorpus contains 24 nuclei as follows: 17 nerve cell nuclei (n_{1-17}), 6 radial nuclei (r_{1-6}), and 1 asymmetric nucleus of questionable significance (x_1). The latter (x_1) lies on the left side of the dorsal sector and 5 to 10μ from the anterior end of the precorpus. The radial muscle nuclei (r_{1-6}) lie near the middle of the precorpus, about 20 to 40μ from its anterior end. These nuclei are arranged as a group of 6, one being on each side of each sector.

The nerve cell nuclei ($n_{1 \text{ and } 2}$) lie near the middle of the dorsal sector, 1 on each side of the duct of the dorsal esophageal gland, 20 to 30μ from the anterior end of the precorpus. Following these nuclei there is a series of 4 nerve cell nuclei[2] ($n_{13-15 \text{ and } 18}$) in the middle of the dorsal sector and external to the duct of the esophageal gland. Of these n_{18} is usually situated at, or posterior to, the level of the marginal nuclei (m_{1-3}), and is therefore grouped as part of the postcorpus. The nerve cell nuclei $n_{3,4,5,10,11,16}$ in the left subventral sector and $n_{6,7,8,9,12,17}$ in the right subventral sector form 2 irregular chains extending throughout the length of the precorpus (Fig. 1), these nuclei being situated near the middle of the subventral sectors. Quite often the last two (n_{16-17}) are posterior to the marginal nuclei (m_{1-3}).

Postcorpus. The postcorpus contains 23 nuclei as follows: 6 radial nuclei (r_{7-12}), 3 marginal nuclei (m_{1-3}), and 14 nerve cell nuclei (n_{18-31}). Of these the marginal nuclei are considered as indicating the anterior end of the postcorpus, 1 being situated to the side of each radius of the esophagus, 2 of these ($m_{1,3}$) usually being dorsal to the subdorsal radii, and the other (m_2) usually being on the right side of the ventral radius.

The first dorsal nerve cell, n_{18}, is usually at about the same level as that of the marginal nuclei. The second and third dorsal nerve cells (n_{23-24}) are situated about 50 to 60μ from the anterior end of the postcorpus, while the last dorsal nerve cell (n_{29}) is situated 10 to 30μ posterior to these. The sub-

[2] Since the nerve cells in the precorpus follow one another so closely, there is considerable chance of error, either by considering the same cell as two cells or considering 2 cells as one and the same. We believe that any error will not involve more than 1 cell for each sector.

ventral nerve cells ($n_{19,21,\text{ and }20,22}$) are situated 10 to 20$\mu$ posterior to the marginals, while the following subventral nerve cells ($n_{25,27\text{ and }26,28}$) are situated 10 to 30$\mu$ posterior to the former (Fig. 1). The last subventral nerve cells of the postcorpus ($n_{30,31}$) are situated at the posterior end of the postcorpus, 10 to 30μ posterior to the last dorsal nerve cell (n_{29}).

The second group of radial nuclei (r_{7-12}) is arranged like the first group (r_{1-6}) and is situated 30 to 40μ from the anterior end of the postcorpus.

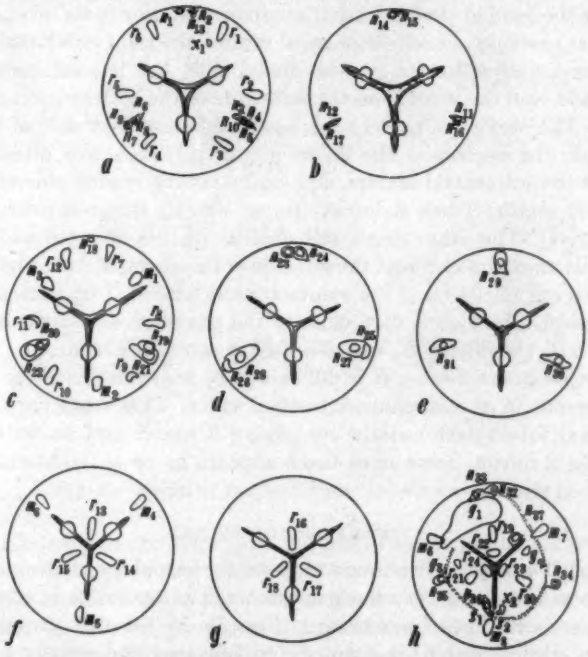

Fig. 1.—Diagrammatic representation of groups of nuclei of the esophagus. (*a–b*) Precorpus; (*c–e*) postcorpus; (*f–g*) prevalvar region; (*h*) valvar and postvalvar region. *s*, *x*, *r*, *m*, and *n* indicate the various types of nuclei.

Isthmian region. This region contains no nuclei.

Prevalvar region. The prevalvar region contains 9 nuclei as follows: 3 marginal nuclei (m_{4-6}), and 6 radial nuclei (r_{13-18}). Of these nuclei the marginals are most anterior, 1 situated near each of the esophageal radii; usually the subdorsal nuclei ($m_{4\text{ and }6}$) are located on the dorsal side of the subdorsal radii, while the ventral nucleus (m_5) is at the left side of the ventral radius.

The 6 radial nuclei are arranged in 2 groups of 3 each, 1 near the apex of each sector; the first group (r_{13-15}) is situated at approximately the same

level as the marginals, while the second group (r_{16-18}) is situated 30 to 50μ posterior to the first.

Valvar and postvalvar regions. The posterior part of the bulbar region contains 21 nuclei as follows: 3 gland cell nuclei (g_{1-3}), 6 radial nuclei (r_{19-24}), 3 marginal nuclei (m_{7-9}), 6 nerve cell nuclei (n_{32-37}), 2 nuclei possibly of nerve cells (s_{1-2}), and an additional nucleus (x_2) observed in some series.

The radial nuclei are arranged in 2 groups of 3 nuclei each (r_{19-21} and $_{22-24}$), one group being anterior to the other. The marginal nuclei (m_{7-9}) are situated near the level of the last radial group or posterior to its level, 1 nucleus situated at one side of each esophageal radius; the right subdorsal marginal nucleus is usually situated on the dorsal side, the left subdorsal on the ventral side, and the ventral on the right side of the corresponding esophageal radii. The nerve cell nuclei n_{32-33} are situated on each side of the dorsal sector near the nucleus of the dorsal gland (g_1); n_{34-35} are situated in the middle of the subventral sectors, and (n_{36}) near the ventral side of the right subventral sector. These 5 nuclei (n_{32-36}) are all situated near the same level (Fig. 1). The other nerve cell nucleus (n_{37}) is situated at about the level of the marginal nuclei at the left side of the dorsal sector. The questionable nerve cell nuclei (s_{1-2}) are symmetrically placed, 1 on each side of the ventral esophageal radius very close to the posterior end of the esophagus. Anterior to s_2 the nucleus x_2 was observed in some specimens.

Esophago-intestinal valve. It is difficult to be sure whether there are 5 or 6 nuclei present in the esophago-intestinal valve. This structure consists of an internal lobed part usually containing 3 nuclei and an external part containing 2 nuclei. Sometimes there appears to be an additional nucleus in the lobed part.

CHARACTER OF NUCLEI

The radial muscle nuclei have a moderately basophilic nucleoplasm which is nearly uniform and very finely granular. The nucleolus is often bilobed (Fig. 2) or sometimes fragmentary (Fig. 2). In the first group of radial nuclei (r_{1-6}) each nucleus is about 5.8 to 7.5μ long and usually compressed laterally; those of the second group (r_{7-12}) about 8μ long and similarly compressed; those of the third and fourth groups ($r_{13-15,16-18}$) about 9.3μ long and usually more rounded than those of the first and second group; those of the fifth group (r_{19-21}) are about 3.3μ long by 5.2μ wide; and those of the sixth group (r_{22-24}) are about 4.2μ long by 2μ wide, very much flattened in a plane parallel with the axis of the esophagus (Fig. 2). Because of their shape the nuclei of the sixth group were previously mistaken for commissural nerve cells by one of us (B. G. Chitwood, 1931). The muscular tissue associated with the nuclei of the sixth group at the level of these nuclei appears as a narrow band.

The marginal nuclei are all rather similar to the radials, each containing a single nucleolus which may be lobed (Fig. 2); the nucleoplasm is usually

less basophilic and less homogeneous than that of the radial nuclei. These nuclei are generally somewhat subtriangular, the narrowest part projecting toward the esophageal lumen. In cross section the nuclei of the first group (m_{1-3}) are approximately 8.3μ long by 4.2μ wide, those of the second group (m_{4-6}) 6.2μ long by 4μ wide, and those of the third group (m_{7-9}) 6.2μ long by 2.5μ wide.

The nucleus of the dorsal esophageal gland (g_1) is extremely large, 19μ long by 14.5μ in maximum width. Anteriorly it appears as a wide sub-

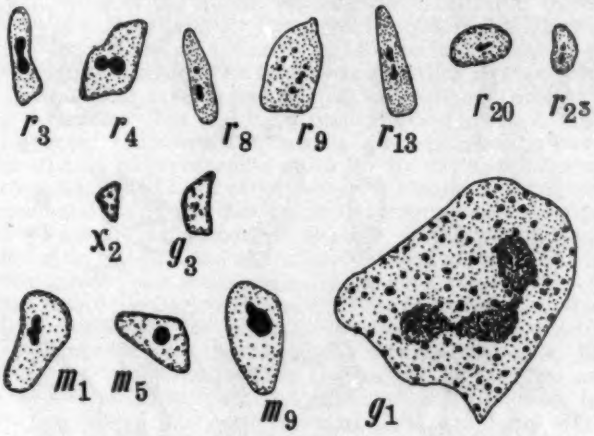

Fig. 2.—Nuclei of the esophagus. Labelled as in fig. 1.

rectangular body in the middle of the dorsal sector; it bends to the right and a narrow lobe projects over the right subdorsal margin of the esophageal lumen. It contains 1 lobed nucleolus or several fragmentary nucleoli. The nucleoplasm is delicate, homogeneous and basophilic, and shows a rather uniform scattering of coarse basophilic granules (Fig. 2). The writers are not absolutely sure that the subventral nuclei (g_{2-3}) actually belong to the subventral glands, but these nuclei appear to be situated in glandular plasma; these nuclei are 5μ long by 2.3μ wide and are similar in character to the marginal nuclei (Fig. 2).

The nerve cells, as in other nematodes, differ markedly in size and shape. Those in the precorpus, as well as the first dorsal nerve cell of the postcorpus, are small; the nuclei (Fig. 3) are stained deeply and are about 1.65 to 2.7μ long by 0.9 to 1.65μ wide. Most of the cells are apparently bipolar, very thin, and spindle-shaped, but the first 2 dorsal nerve cells (n_{1-2}) are subtriangular and may possibly be tripolar. The nerve cells of the postcorpus are all relatively large, and the nuclei stain less deeply than those of the precorpus; each nucleus contains a very small nucleolus and the surrounding

nucleoplasm contains irregular scattered chromatic granules. The nuclei are 1.89 to 4.79μ long by 1.45 to 4.35μ wide, the size varying with that of the cell body. The nerve cells n_{23-24} in the dorsal sector are anterior to the commissure of the corpus, while n_{29} is posterior to the commissure. Likewise the 2 most posterior ventral cells of the postcorpus (n_{30-31}) are posterior to the commissure.

The nerve cells of the bulb are in general similar to those of the postcorpus. Of these n_{33-37} are apparently bipolar, entering into the bulbar commissure, while $n_{36 \text{ and } 37}$ appear to be tripolar commissural cells.

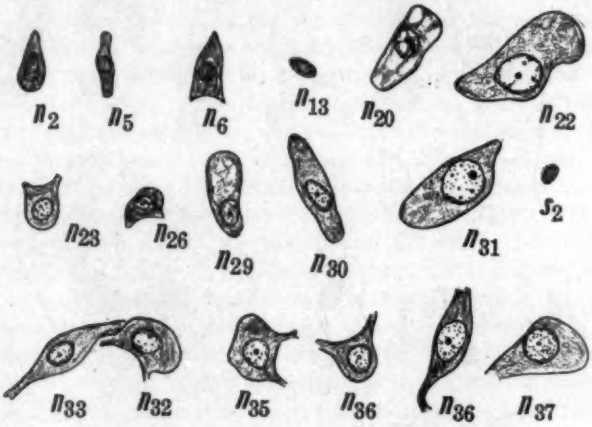

Fig. 3.—Nerve cells of esophagus. Labelled as in fig. 1.

The asymmetric dorsal nucleus (x_1) of the precorpus is 2μ long by 1.65μ wide, and stains somewhat similarly to the nerve cell nuclei of the postcorpus. The nuclei $s_{1 \text{ and } 2}$ are about 1.89μ long by 1.2μ wide, and very strongly basophilic (Fig. 3); these may possibly be nerve cells. The asymmetric nucleus (x_2) in the bulb is 3.3μ long by 1.65μ wide, and smaller than the marginal nuclei, but stains in a similar manner.

Esophageal glands. Nothing can be added at the present time to the description previously given by Chitwood (1931). There is no proof that functional subventral glands are present.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

1071ST MEETING

The 1071st meeting was held in the Cosmos Club Auditorium, May 26, 1934, President DRYDEN presiding.

Program: L. R. HAFSTAD: *Atomic disintegration by high energy particles.*—Our first knowledge of the atomic nucleus was obtained in the discovery of the process of radioactivity by Becquerel in 1896. In 1919 a new branch of unlimited possibilities was started by Rutherford when he produced atomic transmutation for the first time by bombarding nitrogen with alpha-particles. Still another branch was started by Bothe and Becker in 1930, when they discovered that beryllium under alpha-particle bombardment emitted uncharged radiation of extremely great penetrating power. This observation stimulated experiments which led directly to proof of the existence of the neutron in 1932 and very recently, to the discovery of artificially-produced radioactivity. Quite independently, from cosmic-ray studies, Anderson in 1932 discovered the positive electron. As a result of these discoveries we are forced to admit the existence of nuclear processes and reactions much more complex than those originally imagined, which were based on only the proton and the electron as the elementary particles. At the present time a fairly satisfactory theory of the nucleus is being built up but is greatly handicapped by inconsistencies in experimental data. Even the fundamental question as to the mass of the neutron, for instance, cannot be considered as answered as yet for the experiments of Chadwick lead conclusively to the value 1.0067 while those of Curie and Joliot give just as conclusively the value 1.010. The latter experiments also give support for the hypothetical "neutrino." Experimental data are being rapidly accumulated at the present time which will permit such questions to be settled in the near future. Apparatus for the artificial acceleration of particles is proving especially effective since projectiles of mass 1 and mass 2 may be used in addition to alpha-particles for bombarding various elements. This removes one of the great restrictions of the work with radioactive sources in which only alpha-particles can be used. (*Author's abstract.*)

Discussed by Messrs. MOHLER, SEEGER, H. L. CURTIS, DRYDEN, R. E. GIBSON, TUCKERMAN, MEGGERS, and BRICKWEDDE.

Informal Communication: H. L. CURTIS.—There has recently been constructed at the National Bureau of Standards, a precision coil for a current balance in which the winding consists of two strips of aluminum wound simultaneously on an aluminum frame, and insulated from each other and from the frame by aluminum oxide. The strips are 6 mm wide by 0.07 mm thick, and the aluminum oxide coating, which was deposited on the strips electrolytically, is a few microns in thickness. An arrangement was made for wiping each strip with chamois just before it was wound on to the coil, thus preventing short circuits between the turns. With 45 turns in each winding, the insulation resistance between the windings, when the coil is dry, is several megohms. (*Author's abstract.*)

Discussed by Messrs. MOHLER, GISH, and TUCKERMAN.

1072ND MEETING

The 1072nd meeting was held in the Cosmos Club Auditorium, October 13, 1934, President DRYDEN presiding.

Program: W. E. DEMING: *Curve fitting and tests for empirical formulas.*—A review was given of the sampling distributions of the mean $\bar{x}$ and the standard deviation (S. D.) s in samples of n drawn from a normal parent population of mean μ and S. D. σ. When χ^2 is defined as ns^2/σ^2, the sampling distribution of χ^2 can be found immediately from the distribution of s. The single set of n observations constitutes the simplest possible problem in curve fitting; the line $x=a$ is to be fitted to the n observations to make s, and hence χ^2, a minimum. No matter how complicated the formula, the sampling distribution of χ^2 (defined as the sum of the weighted squares of the residuals, each residual being measured in units of σ, the r.m.s. error of observations of unit weight) is always a member of a certain one-parameter family of curves, the single parameter being k, the *number of degrees of freedom*, as it has been called by Fisher. k is the number of points fitted diminished by the number of independent adjustable constants in the empirical formula. From the distribution of χ^2 it is found that the average value of χ^2 is k, the number of degrees of freedom in the problem.

An unusually high value of χ^2 may arise from (a) pure chance; (b) the wrong empirical formula; (c) lack of control, or the presence of constant errors; (d) too low an assumed value of σ, the S. D. of observations of unit weight. To decide just which cause or causes may be operating in a given problem to give an unusually high value of χ^2 is a matter that requires caution and skill in interpretation, but it is important to note that a statistical analysis of the situation often leads to the detection of causes (b) and (c). In the case of a pair of means, the Chi-test is the same criterion as the test derived from the normal distribution of the difference of two means. In any problem the tables of $P(\chi^2)$ tell how unusual a given value of χ^2 is for different values of k.

When there is no opportunity of getting beforehand a reliable estimate of σ, another method of attack is by the *analysis of variance*, as it is called by Fisher. This consists of comparing the ratio ω of two estimates of σ. If σ' and σ'' denote the two estimates of σ that are obtained respectively by external and internal consistency (Birge, Phys. Rev. **40**: 207 1932), the ratio $\omega=\sigma'/\sigma''$ may be unusually high from the same four causes as outlined in the preceding paragraph, and the interpretation is exactly similar. Tables are provided by Fisher's *Statistical methods for research workers* and by Pearson's *Tables of the incomplete beta function*. In the case of a pair of means, this method reduces to the t-test devised by Student and Fisher.

Discussed by Messrs. WERTHEIMER, MCNISH, TUCKERMAN, NAIMAN, WULF, SILSBEE, and GOLDBERG.

Informal Communication: L. B. TUCKERMAN.—Mr. TUCKERMAN read a translation of a part of a communication entitled *Stilarten mathematischen Schaffens* by L. Bieberbach in the July 1934 number of the *Sitzungs Berichte der Preussischen Akademie der Wissenschaft* and a quotation from Hardy in *Nature*, No. 3381, August 18, 1934, commenting on this communication of Bieberbach.

F. G. Brickwedde, *Recording Secretary*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

U. S. Department of Agriculture.—More than 100 guests attended the dedication services on October 20, of the new Zoological Laboratory building which has just been completed at the Beltsville Research Center, Beltsville, Md. Dr. MAURICE C. HALL, chief of the Zoological Division of the Bureau of Animal Industry, presided. Among the speakers were: Dr. COOPER CURTICE, who was the first member of the division and is now retired; Dr. CHARLES WARDELL STILES, who served as chief of the division; Dr. ALBERT HASSALL, who until his recent retirement was assistant chief; Dr. HENRY B. WARD, permanent secretary of the American Association for the Advancement of Sciences; Dr. W. E. COTTON, superintendent of the Bureau of Animal Industry Experiment Station at Bethesda, Md.; Dr. LAWRENCE A. AVERY, superintendent of the new laboratory; and EARL C. BUTTERFIELD, newly appointed superintendent of the Beltsville Research center.

FREDERICK D. RICHEY has succeeded KNOWLES A. RYERSON as chief of the Bureau of Plant Industry, United States Department of Agriculture, effective October 23, 1934. Mr. RYERSON has resumed his earlier work with tropical fruits and will head a section of subtropical horticulture in the Bureau. Mr. RICHEY has been in the Bureau for more than twenty-three years, having headed the corn-breeding project in the Division of Cereal Crops and Diseases until January 1 of this year, when he was appointed Associate Chief of the Bureau. Dr. M. A. MCCALL, head of the Division of Cereal Crops and Diseases, and Dr. E. C. AUCHTER, head of the Division of Fruit and Vegetable Crops and Diseases, have been designated as assistant chiefs of the Bureau, but will continue also to direct the work of their respective divisions. H. E. ALLANSON, in charge of administrative operations, will continue in the same capacity with the title of business manager.

At the autumn meeting of the American Ornithological Union, held in Chicago, October 22 to 26 inclusive, the Bureau of Biological Survey was represented by the following: W. C. HENDERSON, W. B. BELL, W. L. MCATEE, F. C. LINCOLN, CLARENCE COTTAM, H. C. OBERHOLSER, E. A. PREBLE, E. A. GOLDMAN, A. H. HOWELL, C. H. M. BARRETT, Miss PHOEBE KNAPPEN, and J. PAUL MILLER.

The following papers were presented by Biological Survey representatives: W. B. BELL, *Some sidelights on the waterfowl breeding grounds;* CLARENCE COTTAM, *The waterfowl situation;* F. C. LINCOLN, *The four major waterfowl flyways;* E. A. PREBLE, *Waterfowl breeding grounds of northern Canada;* Miss PHOEBE KNAPPEN, *A neglected food resource.*

National Bureau of Standards.—On the evening of October 27, Dr. LYMAN J. BRIGGS, director of the National Bureau of Standards addressed the Washington Philosophical Society at the Cosmos Club on the stratosphere flight of the balloon *Explorer*. He was followed by Dr. L. B. TUCKERMAN of the engineering mechanics section who spoke on the technical difficulties in stratosphere ballooning.

Dr. H. C. DICKINSON recently completed road tests which indicate that on a highway where the speed limit is 45 miles an hour, and cars traveling 50 miles an hour are tolerated, a distance of 900 feet is needed for safe clearance. Time of passing is found to be nearly constant at six seconds on a level road and does not depend on the speed.

Dr. PAUL R. HEYL, chief of the sound section, was severely injured in an automobile accident on October 20, suffering the loss of his right arm.

Dr. H. C. DICKINSON, chief of the heat and power division, spoke before the American Road Builders' Association at the National Press Club on October 30.

V. B. PHELAN, of the specifications division, attended a preview of the housing exhibition sponsored by the New York City Housing Authority at the Museum of Modern Art in New York City, as well as conferences on slum clearance and low-cost housing at Columbia University, on October 15 and 16. The Bureau prepared and installed an exhibit illustrating its activities in connection with materials, equipment, and services used in dwelling house construction. This exhibition opened on October 15 and continued through November 7.

Dr. F. S. BRACKETT of the Bureau of Agricultural Economics will devote part of his time to studies of sources of ultraviolet radiation as a special guest worker in the pyrometry section of the National Bureau of Standards.

C. J. HUMPHREYS, formerly a member of the Bureau's spectroscopy section, has joined the physics department of the Massachusetts Institute of Technology.

U. S. National Park Service.—A special session of the National Park Educational Advisory Board was held in Washington, November 9 and 10. This session was called primarily to enable the members of the board to discuss national park wildlife problems with GEORGE M. WRIGHT, chief of the Service's Wildlife Division, and BEN H. THOMPSON, also of that Division, who have been in Washington preparing the Recreation Section of the National Resources Board Report. The winter feeding grounds of the elk in Yellowstone National Park and the Trumpeter swan in Yellowstone were given special consideration at the meeting.

Invitations have been issued by Director CAMMERER to national park superintendents, monument custodians, and field officials to attend a Superintendent's Conference in Washington, D. C., November 19, 20, and 21. It will be the purpose of the conference to consider important matters relating to the areas under the Service's jurisdiction and to discuss new policies that should be put into effect, or to be considered for adoption, as a result of changed conditions occasioned by the development of emergency programs and the increased use of park and monument areas by the public.

National Zoological Park.—The first barless pit to be installed at the National Zoological Park is now in use; at present it houses a number of flightless cormorants and swans. New acquisitions include a male muntjac, the first in Washington since 1910, mates for the kiang and the Indian blackbuck, a pair of barking garcias and three terra-terras.

The Roerich pact.—President ROOSEVELT has appointed Secretary of Agriculture HENRY A. WALLACE as United States plenipotentiary to sign the Roerich Pact. A treaty for American republics to sign has been drawn based on Nicholas Roerich's proposals. It provides that the nations regard as inviolable all artistic and scientific institutions and historic monuments. In event of fighting between American countries, the armies would respect sites marked with a banner, to be known as the Banner of Peace. No bombs would be dropped on cathedrals, museums, schools, universities, libraries,

or other cultural sites. These would be neutral territory, respected by all nations signing the treaty. The governments that have so far given notification of signing are Panama, Honduras, Uruguay, Ecuador, Guatemala, and the United States. The plan for protection of the world's scientific and artistic treasures against the destructiveness of war was presented by Roerich as far back as 1904. Had it been acted upon then in Europe, the Banner of Peace might have saved museums and other irreplaceable buildings and their contents, that were needlessly destroyed during the World War.

Optical Society meeting.—The Optical Society of America held its nineteenth annual meeting at the National Bureau of Standards, October 18 to 20. Among the outstanding contributions were papers by Dr. J. W. BEAMS of the University of Virginia, who reported that the human eye "sums up" or integrates into an apparent continuum the energy of a series of exceedingly short light flashes; by Dr. HAROLD MESTRES of Yale University, who described a densitometer method for studying the increase of bacteria in fluid cultures; and by Dr. ROGER S. ESTEY of the Electrical Testing Laboratories, New York City, on the use of heat-absorbing glass in air-conditioning installations where solar radiation is a considerable factor.

Child development meeting.—A meeting of the Society for Research in Child Development was held at the headquarters building of the National Academy of Sciences and the National Research Council, November 3 to 5. Among the speakers was Dr. JULIUS H. HESS of Chicago, who related progress in reducing the deathrate among prematurely born infants. Deathrate in such cases, born in hospitals, was reduced from 42 per cent in the period 1922–26, to 22.5 per cent in 1930–33. Dr. RUSSELL W. BUNTING of the University of Michigan reported a strong positive correlation between low-sugar diet and low incidence of dental caries in children. Dr. PAUL HANLY FURFEY of the Catholic University of America challenged the validity of much of the statistical analysis of child mentality measurement methods at present in vogue.

Memorial meeting at Ames.—At a meeting held at Iowa State College, Ames, on November 16 and 17, in commemoration of sixty years of modern plant study, inaugurated by the late Prof. CHARLES EDWIN BESSEY, Secretary of Agriculture HENRY A. WALLACE delivered an address on Sixty Years of Corn Breeding. The Soil Erosion Service of the U. S. Department of the Interior was represented at the meeting by R. E. UHLAND and Dr. W. C. LOWDERMILK, and the Bureau of Plant Industry, U.S. Department of Agriculture by A. F. DODGE.

Department of Terrestrial Magnetism.—Dr. J. BARTELS, research associate of the Carnegie Institution of Washington and professor of geophysics at the University of Berlin, and at the Forstliche Hochschule in Eberswalde, Germany, who has been engaged in research work at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, since early in August, spoke at the staff meeting of the Department, October 17, on *Random fluctuations, persistence and quasi-persistence in geophysical and cosmical phenomena.* He sailed from New York en route to Germany on October 19.

F. T. DAVIES, of the Department of Terrestrial Magnetism, who was granted a furlough in order that he might take charge of the Canadian Polar-Year station at Chesterfield Inlet and assist in discussion of the results at the Meteorological Service in Toronto, returned to duty at the Department in Washington October 15.

NEWS BRIEFS

The annual meeting of the Official Agricultural Chemists was held in Washington, October 19 to 21.

A Committee on Hydrogen Isotopes has been organized under the auspices of the National Research Council, with Prof. H. C. UREY of Columbia University as its chairman. Drs. F. G. BRICKWEDDE and M. A. TUVE of the National Bureau of Standards are members of this committee.

Reorganization of Patent Office practice is advocated by D. H. KILLEFER of New York City, in a communication to the American Chemical Society. Mr. KILLEFER calls for less secrecy surrounding applications for patents, and for better salaries and more privileges for searchers, with the aim of building up a better trained and more permanent staff.

A shoal water fathometer has been perfected in the laboratories of the U. S. Coast and Geodetic Survey. It operates on the echo principle, already in use in the deep water fathometer, but improvements in accuracy permit measurements within a one-inch margin of error, and enable observers to read soundings, if desired, for every foot of bottom traversed at a cruising speed of ten knots.

The airship *Los Angeles* has been reconditioned as for cruising, but is to be kept on the ground and used only for mooring tests.

The U. S. Naval Observatory has inaugurated a new time-broadcasting schedule, putting the time signals on the air from the Station NAA, Arlington, twenty times every day. The signals are sent out every hour on the hour, except at 9 and 11 A.M. and 9 and 11 P.M., E.S.T., on a long wavelength of 113 kilocycles. The code broadcasts hitherto in use are also being continued.

The U. S. Weather Bureau reports only two tropical disturbances of hurricane force in West Indian waters during the past autumn, as compared with an all-time record number of 21 during the corresponding season of 1933.

New measurements and calculations by Dr. E. O. HULBURT of the U. S. Naval Research Laboratory indicate that the atmospheric temperature above the earth may be as high as 300 degrees Kelvin, or 80.6° Fahrenheit.

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